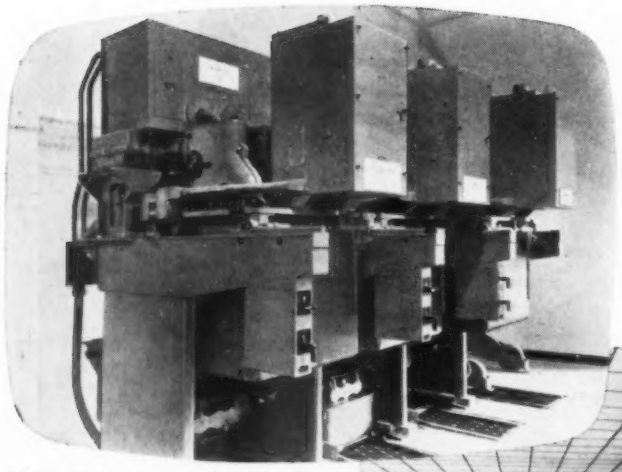
Fully tested, including full load heat run and impulse tests at 1035 kV and 1550 kV respectively

The transformers shown above comprise the third of six 60 MVA, 220 kV transmission transformers and two of ten 80 MVA, 330 kV generator transformers.

'ENGLISH ELECTRIC'

transformers

JUN 19 1953



Photographs by courtesy of the U.K.A.E.A.

generator switchgear at Calder Hall

The generators at the Calder Hall Power-station of the Atomic Energy Authority are controlled by Reyrolle 11-kV 500-MVA and 750-MVA switchboards and their associated control-boards

Reyrolle equipment is also installed at:
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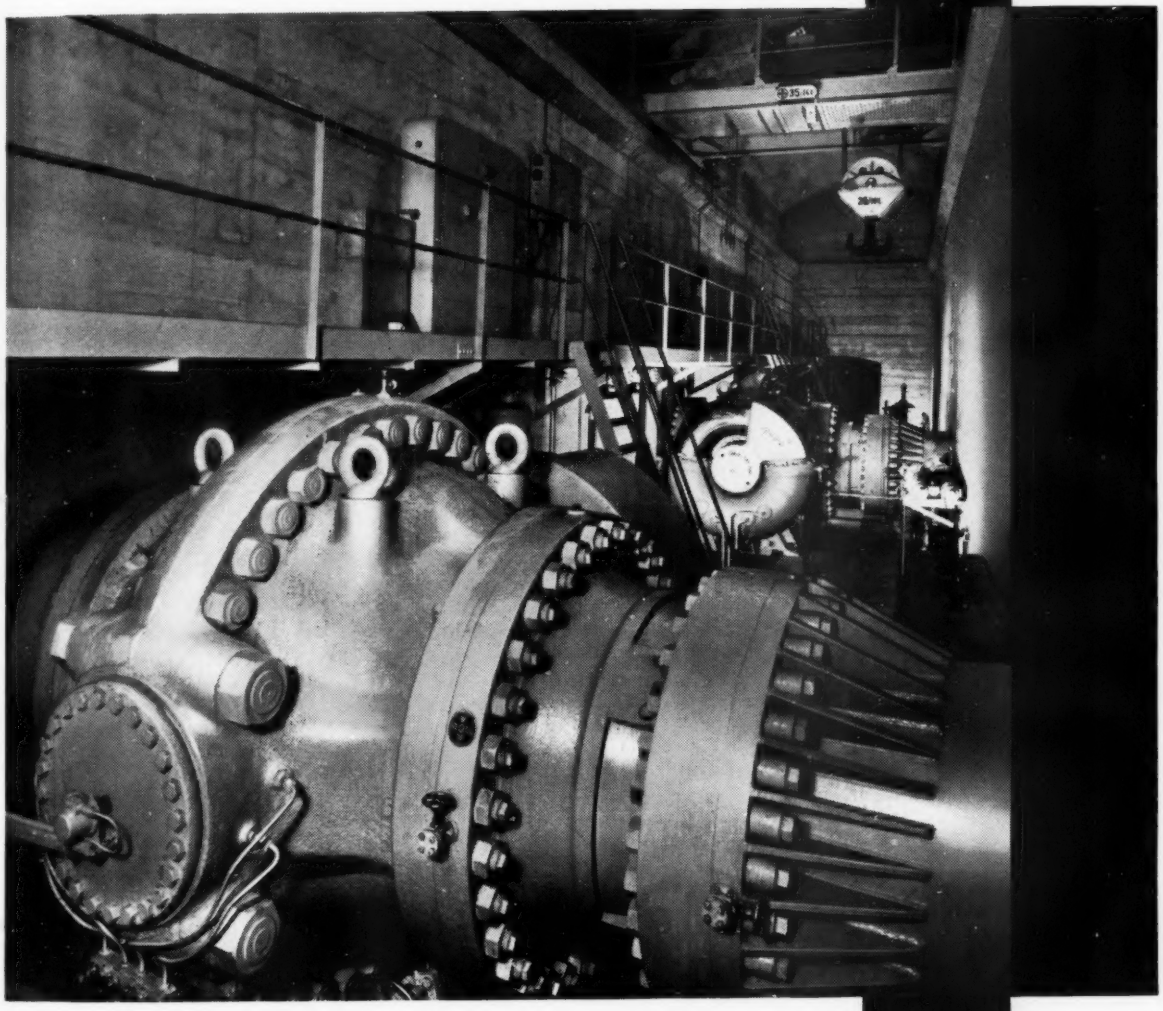

Valve chamber with rotary slide sphériques valves as turbine shut-off device in a swiss power station

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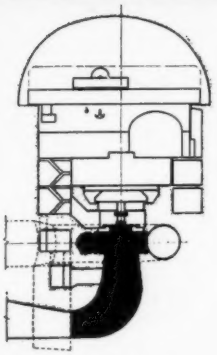
KARIBA—ON SITE—ON SCHEDULE

The Stay Ring for No. 1 Turbine at Kariba—shipped from England in May, 1958—is now in position. It is shown here installed in the vast underground power station, ready for the next major step, fabrication of the spiral casing.

This is the first of six Boving Turbines being installed at Kariba. Each is of 140,000 b.h.p.



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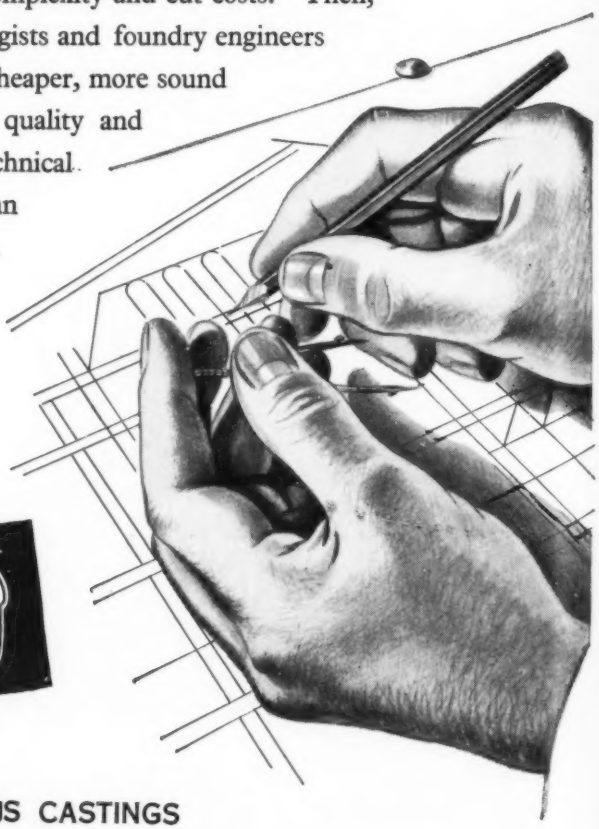

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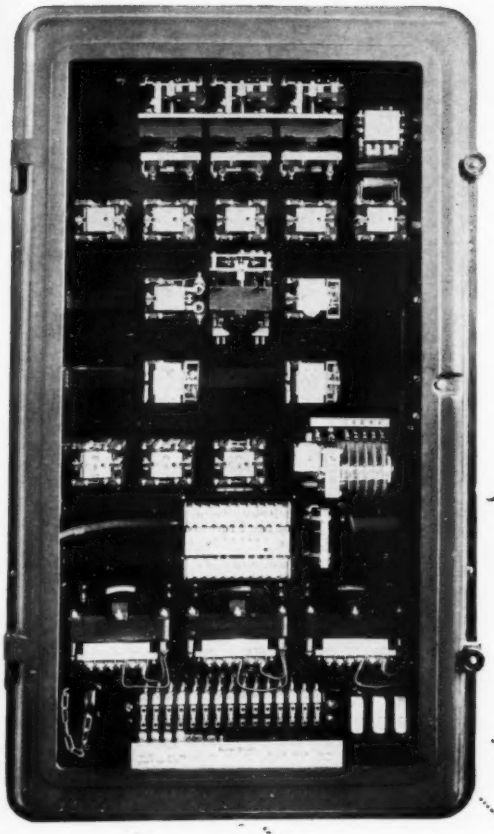

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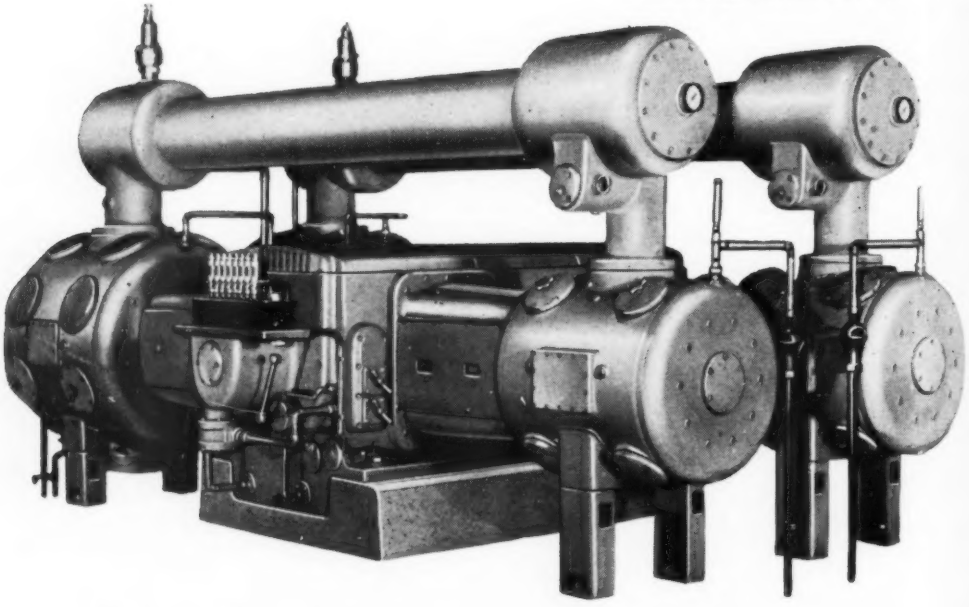
Class "FE" compressors are suitable for handling gasses other than air.



The advantage of standard Consolidated Pneumatic "FE" class compressor units is that they can be built up into single or multi-stage installations giving outputs up to 5,000 c.f.m. or pressures up to 3,000 p.s.i. to suit *exact individual* requirements, thus giving the most efficient return in terms of air delivered for power consumed. And, because the machines consist of standard units, the basic engineering cost of the plant as a whole is lower. Further, the virtues of the balanced-opposed design of these units are such as to effect considerable savings in foundation work, floor space and maintenance costs. In every way, "FE" compressors mean air at lower cost.

A Consolidated Pneumatic four-cylinder, four-crank, two-stage, double-acting horizontal balanced-opposed Class FE-42 Compressor. This unit requires 650 H.P. and delivers 3600 c.f.m. at 100 p.s.i. working pressure.

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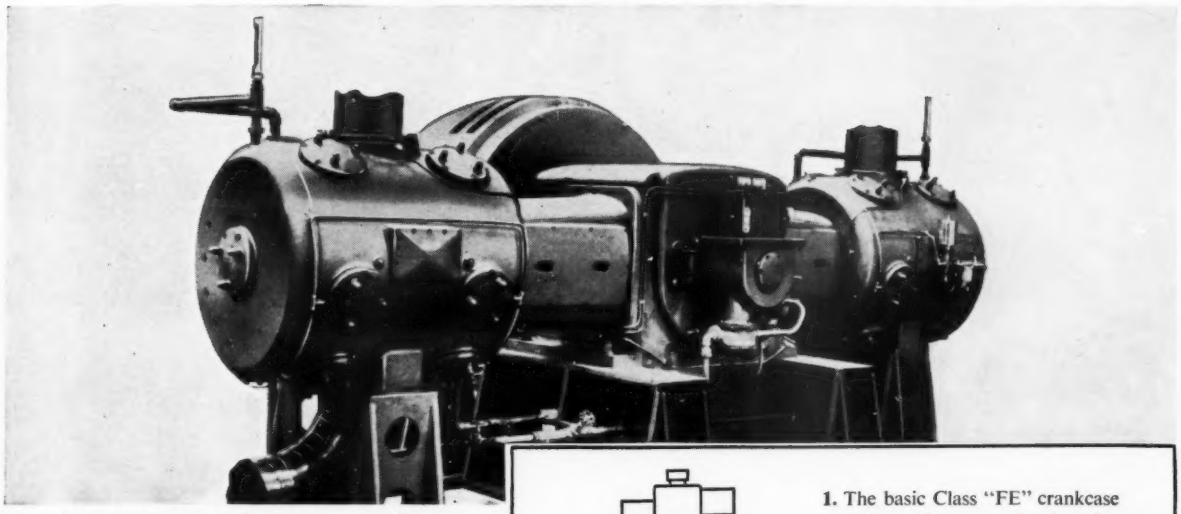
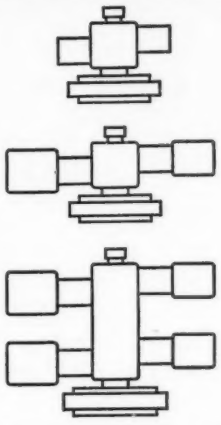
*** up to 5000 c.f.m. or 3000 p.s.i.**



A two-cylinder, two-crank, single-stage, double-acting, horizontal balanced-opposed Class FE-21 Compressor. This unit requires 300 h.p. and is designed for 2500 c.f.m. at 40 p.s.i. Picture shows plant on the test bed in the Consolidated Pneumatic works, Fraserburgh, prior to delivery for operation by Charles Brand & Son Ltd., on the Clyde Tunnel contract.

ADVANTAGES OF THE BALANCED-OPPOSED DESIGN

In the "FE" compressors, the crankcase and frame are centrally positioned with cylinders on opposing sides, the drive being obtained by a double-throw crankshaft. The resulting perfect dynamic balance makes for far greater compactness and virtual freedom from vibration, space and foundation work being reduced to a minimum. Also, the considerably smaller load imposed on main bearings, together with slow operating speed, ensure an extremely long life of continuous operation with very little maintenance.



1. The basic Class "FE" crankcase and running gear, showing also compactness achieved by using engine-type, salient-pole motor.
2. Different-size cylinders can be fitted, one-, two-, three- or four-stage machines being available.
3. Large outputs are obtained by increasing the number of cylinders and working off a common crankshaft.

For further information complete this form and pin it to your letter heading.

No. 40

This form will bring you a descriptive catalogue on Class "FE" Compressors, but if you would like advice on a projected plant, your enquiry can be dealt with more expeditiously if the following information can be provided:

1. Output required in cubic feet per minute at intake pressure and temperature. .....
2. Intake temperature and humidity. .....
3. Intake pressure. .....
4. Discharge pressure. .....
5. Type of drive motor, voltage, etc. .....
6. Temperature of cooling water and type of cooling circuit. .....
7. Aftercooler, if required, and temperature of air at discharge from aftercooler. .....
8. Purpose for which compressor is to be used. .....

CPI65

COMPRESSORS

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the world over...

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This 150-B dragline is one of five Bucyrus-Erie excavators engaged on the gigantic Serre-Poncon earth dam project on the Durance river in Southern France.

In Switzerland

Operating at 9,000 ft. above sea level are five Bucyrus-Erie 54-B 2½ cu. yd. Ward-Leonard electric shovels loading blasted moraine rock for the huge concrete dam at Grande Dixence, Switzerland. Bucyrus-Erie excavators were preferred for their reliability in these tough conditions.

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Development begins with excavation and for the dam construction at Damirköprü five 54-B machines are used. The Hydraulic Works Administration of Turkey are another organisation which prefers Bucyrus-Erie equipment.

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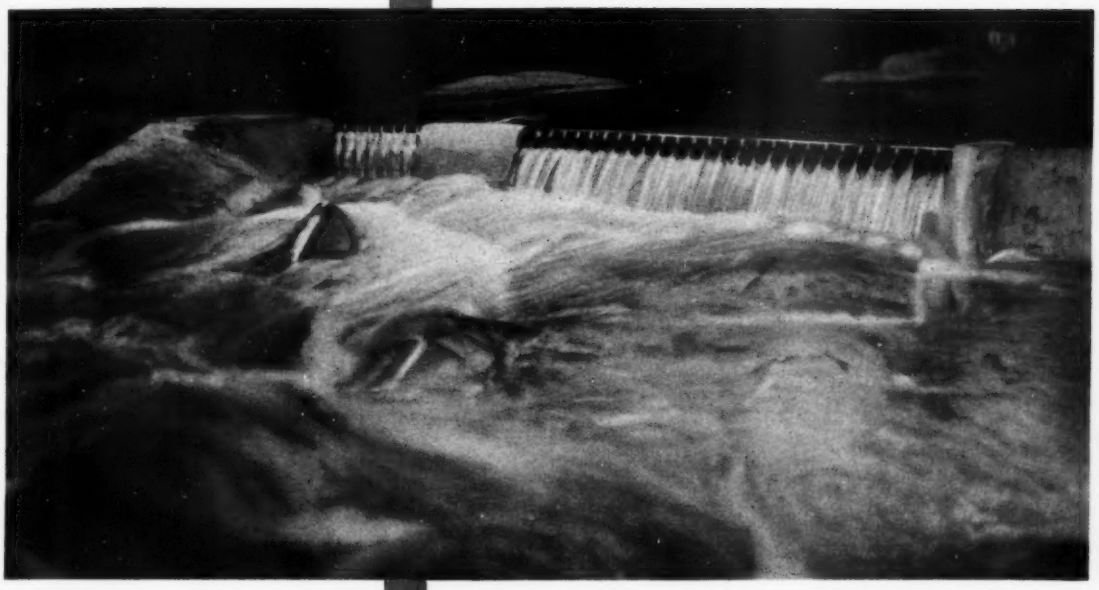

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In their own laboratory M·A·N investigate and test on models all problems relating to hydraulic engineering. Here in the picture, the model of a large weir plant with 35 openings is set up. What is being checked in this instance is the appropriate position and shape of the gates, weir axis and turbine intake channel. Erosion behind the weir was, by correct shaping, brought down to a minimum, and silting-up of the catchment basin upstream of the weirs eliminated in the simplest and safest manner.

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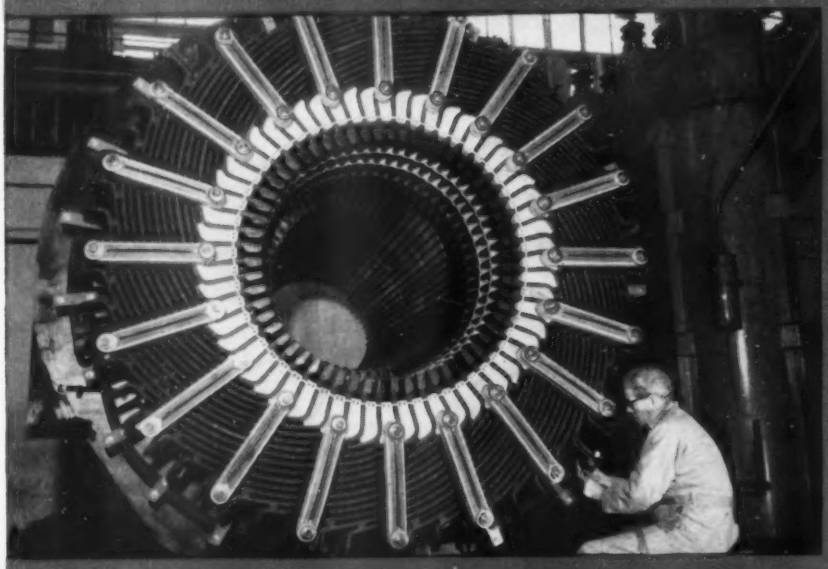

"PAXOLIN" and **MICANITE** are incorporated in the 23 MW air cooled turbo-generators at Chapel Cross Nuclear Power Station—another example of our service to the electrical industry.

Photographs:—(top) by courtesy of the U.K. Atomic Energy Authority. (lower) by courtesy of C. A. Parsons & Co., Ltd.

m and **i** the electrical insulation people

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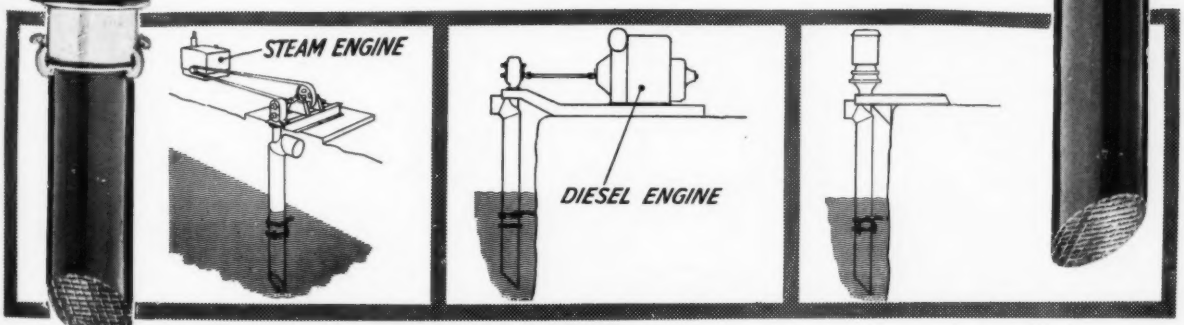

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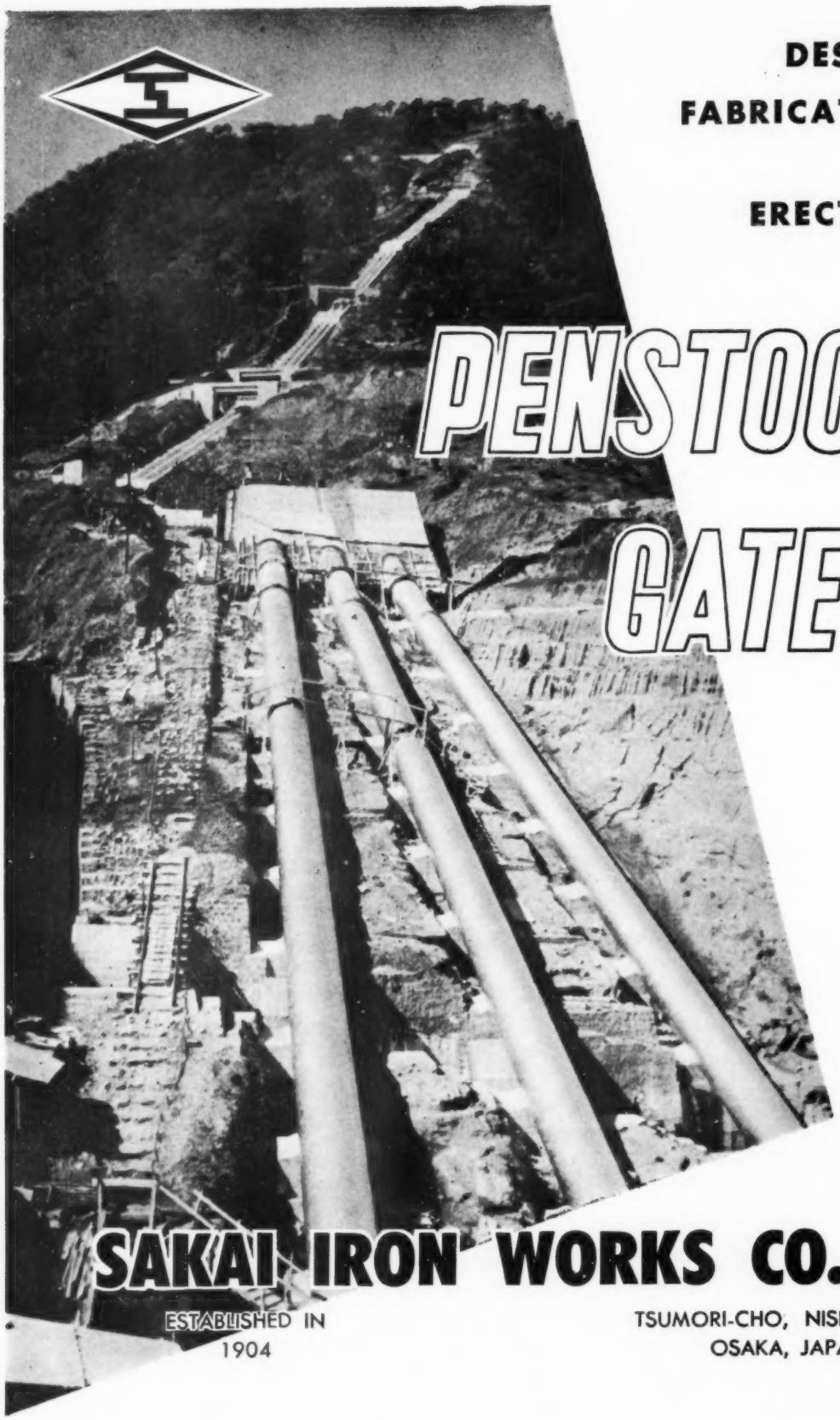

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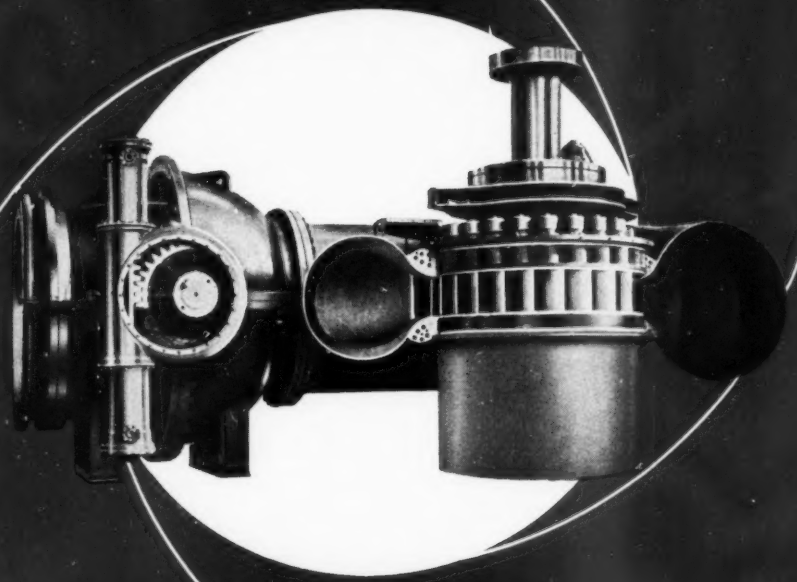

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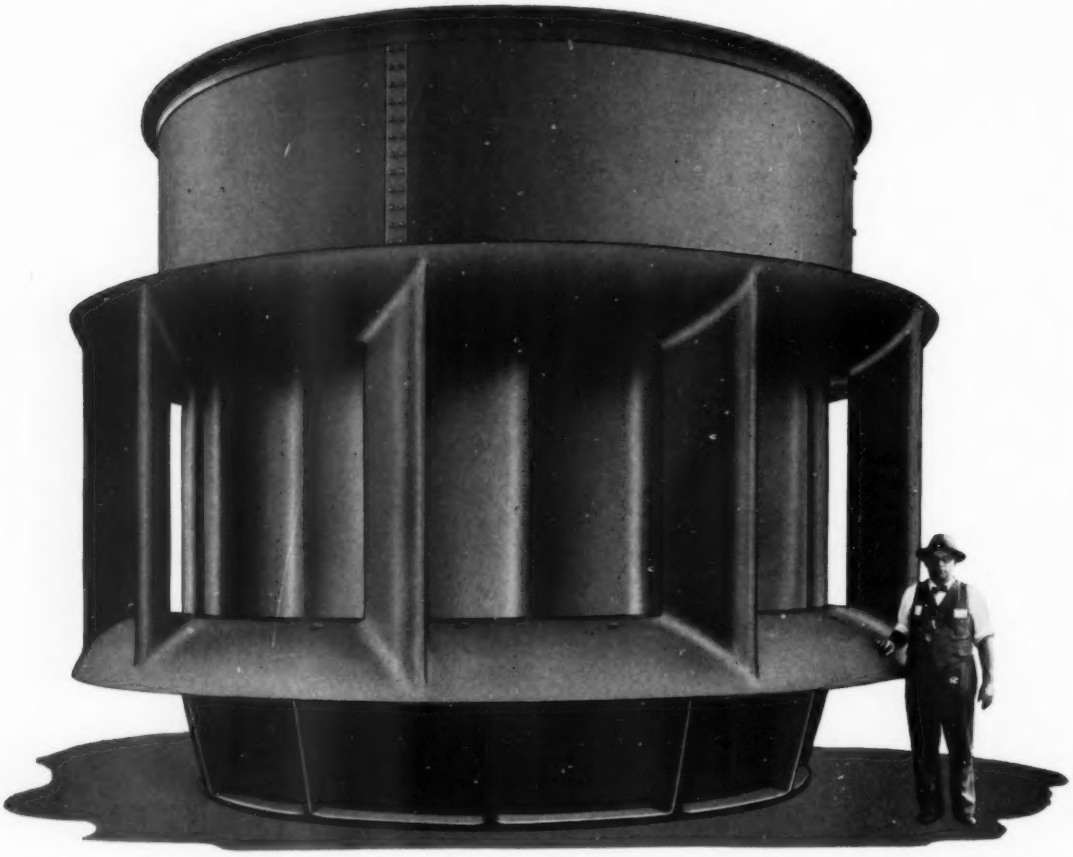

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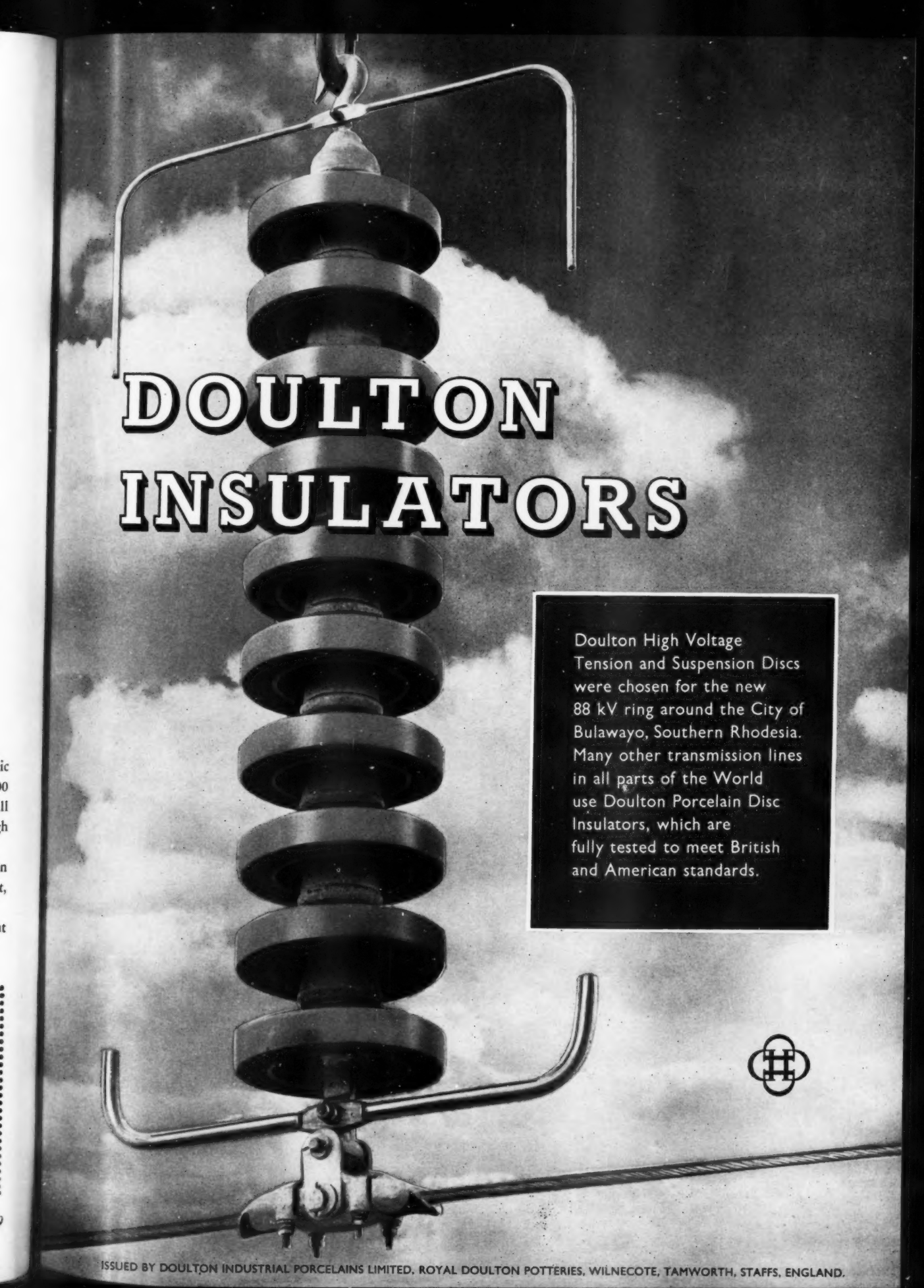
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INSULATORS
Doulton High Voltage Tension and Suspension Discs were chosen for the new 88 kV ring around the City of Bulawayo, Southern Rhodesia. Many other transmission lines in all parts of the World use Doulton Porcelain Disc Insulators, which are fully tested to meet British and American standards.
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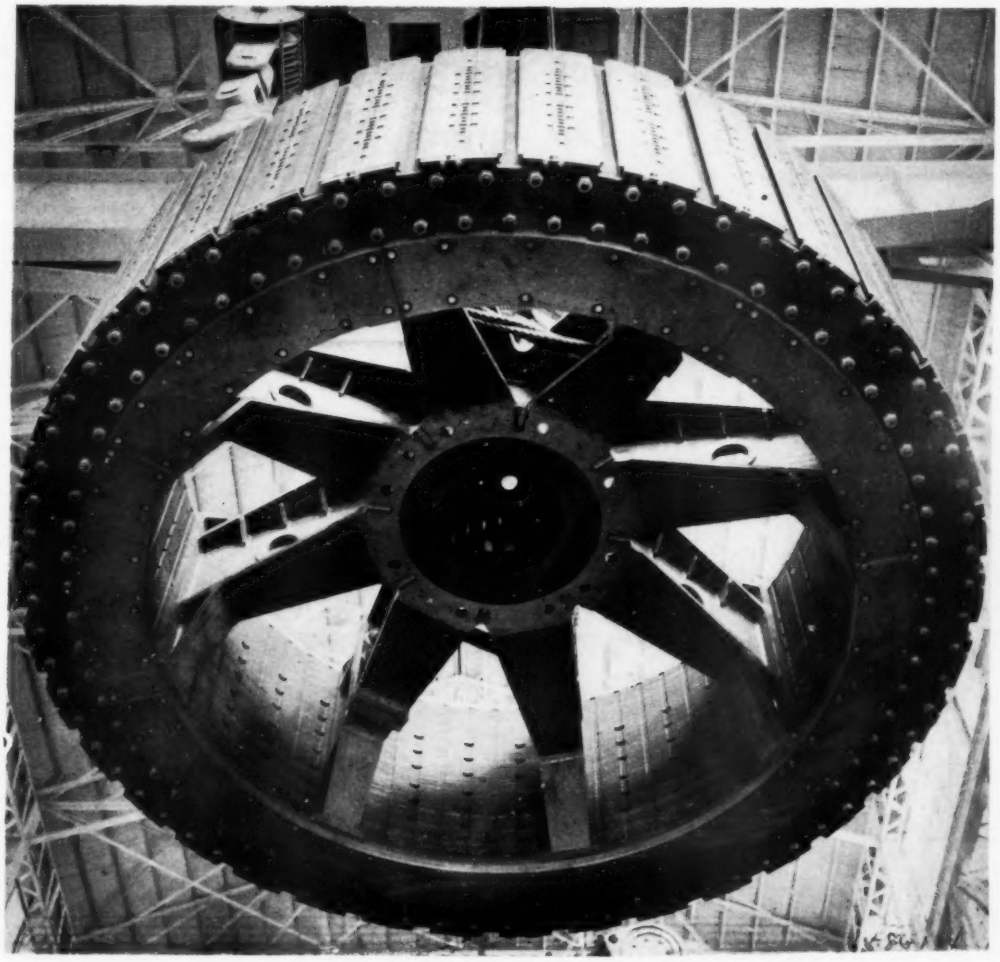

Massive AC Generator for Brazil

Capacity	Voltage	Frequency	Speed
83,000 KVA	13.8 KV	60 cps	200 r.p.m.

The two largest AC generators ever built in Japan for export were completed by Hitachi last January. They were destined for the Paulo Afonso Power Station of Compannia Hidro Electrica Do Sao Francisco and situated on Brazil's San Francisco River — the hub of a gigantic hydro-power grid serving northern Brazil, with a capacity of 1,000,000 KVA.

These umbrella-type alternators incorporate a number of new developments. The rotor spider, for example, was constructed of welded steel to effect a considerable reduction in rotor weight. A new, synthetic resin gives added durability and insulation for the coil. The segment-type bearings eliminate the need of an oil pump. These and other improvements are products of the world's most advanced electro-mechanical technology.

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Tokyo Japan

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Licensed by Baldwin-Lima-Hamilton Corp.
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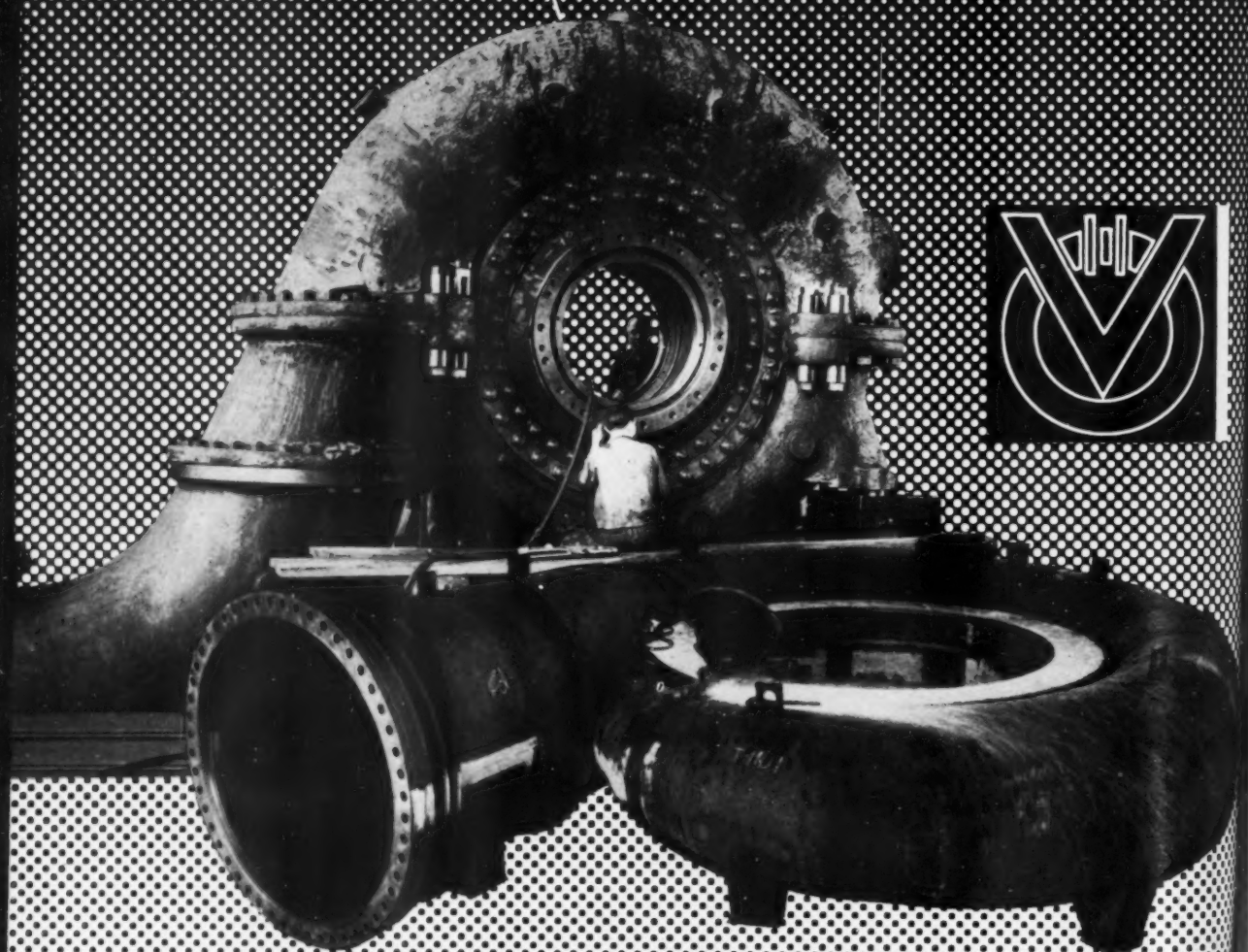
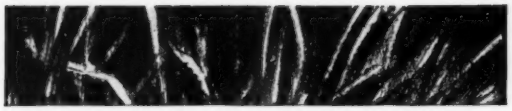


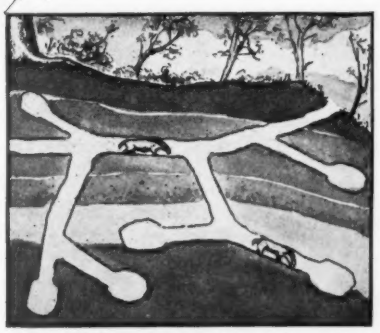


Underground movement

A long tunneller and a strong tunneller, the badger builds himself an intricate web of passages and dens in which to evade pursuit or retire from the noisy world outside.

It's a paradox of progress that man too—in getting even further away from nature—is going more and more underground. Tunnels for hydro-electric schemes, underground power houses—these and many other engineering feats are the work of man the tunneller—a skill which we have developed into a fine art. * *

* * In driving 40 miles of tunnels for the North of Scotland Hydro-Electric Board, Mitchell Construction captured and hold the World high speed rock-tunnelling record and constructed the first major underground power station in Britain.



Many of these badger 'sets' have been enlarged and improved through successive generations and may extend for hundreds of feet into a hillside.

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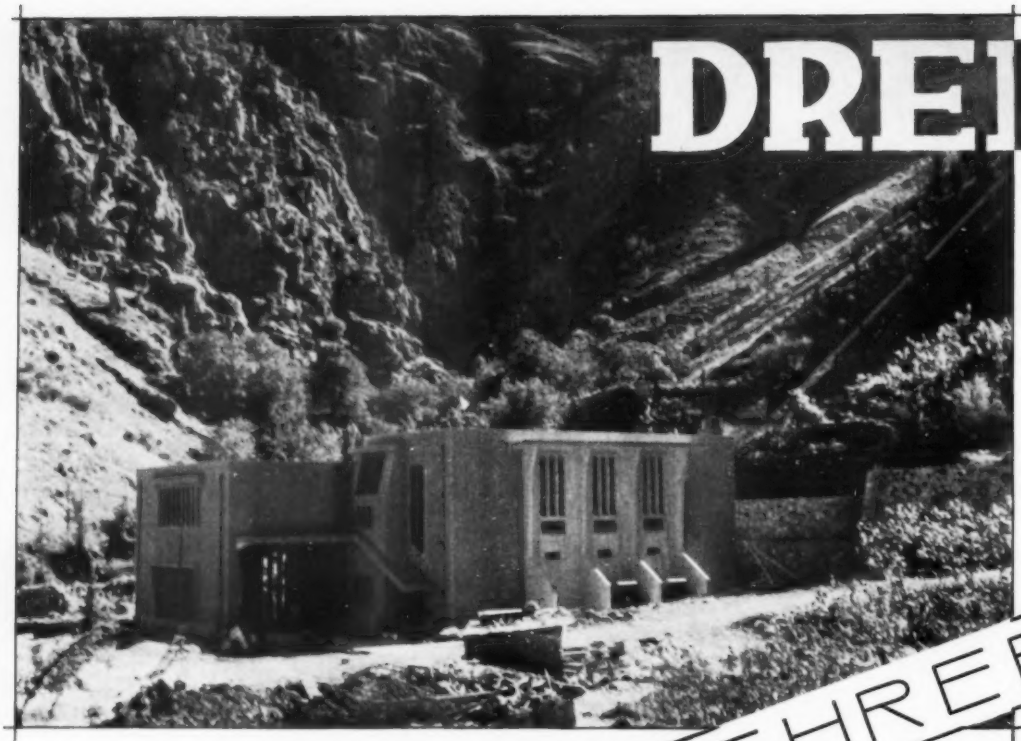
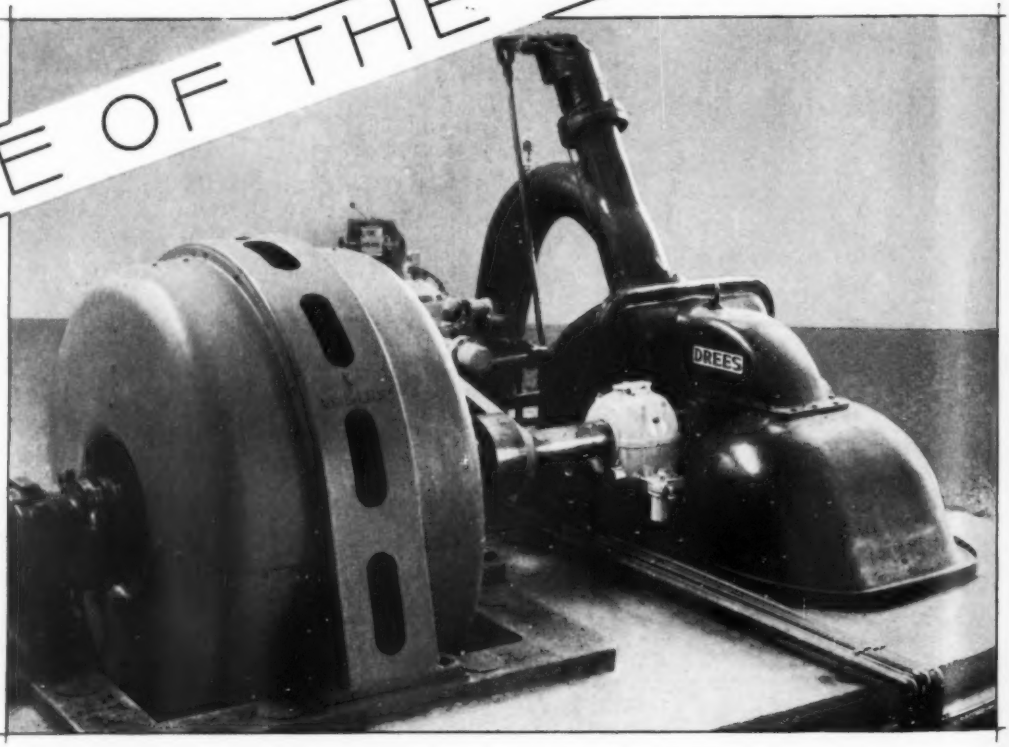


ONE OF THE THREE...



Turbo-Generator Sets supplied to Power Station MAR LICHA

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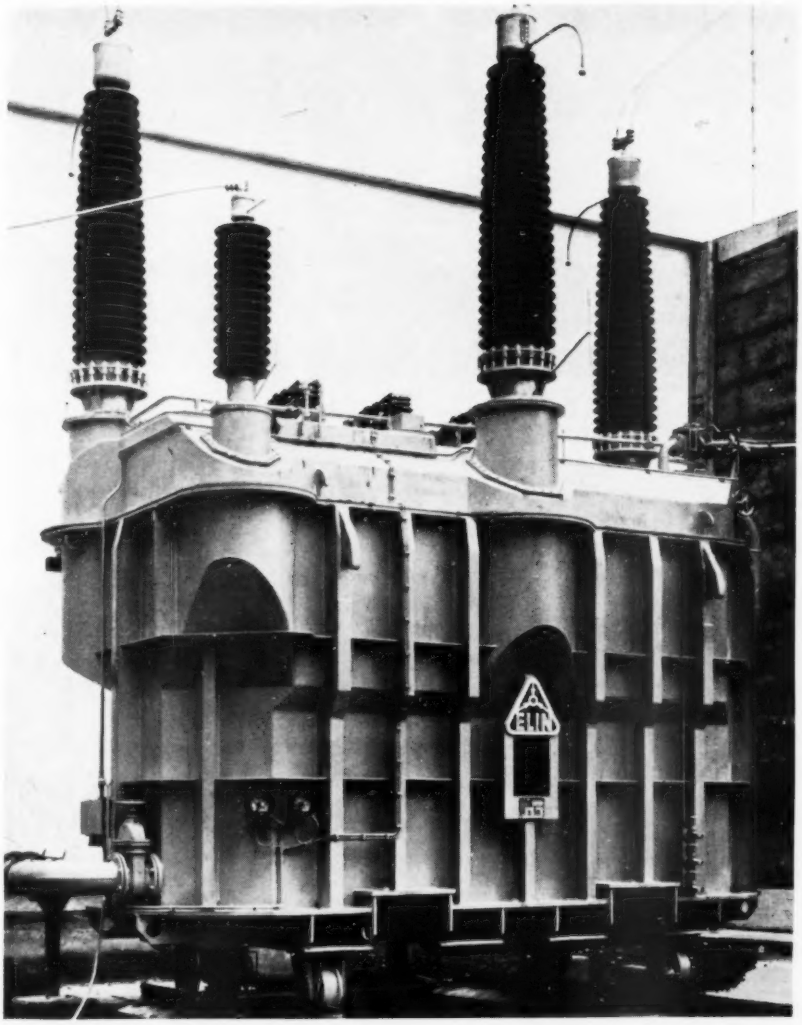
POWER TRANSFORMERS



One of the 56,000 kVA., 50 c.p.s., 10,500/240,000 V. generator transformers, having star-delta connections and OFW. cooling, with heat exchangers, supplied by ELIN to the Lünersee power station of the Vorarlberger Illwerke Aktiengesellschaft.

Lünersee is at present the largest high-head pumped-storage plant in the world and is designed to co-ordinate power production between the Vorarlberg hydro-electric development and thermal plant in the Rheno-Westphalian area. Special automatically-controlled equipment is installed for quick change-over from generation to pumping so that power can be supplied at will either to the German Federal Republic system or to the pumped-storage plant at Lünersee.

"ELIN"

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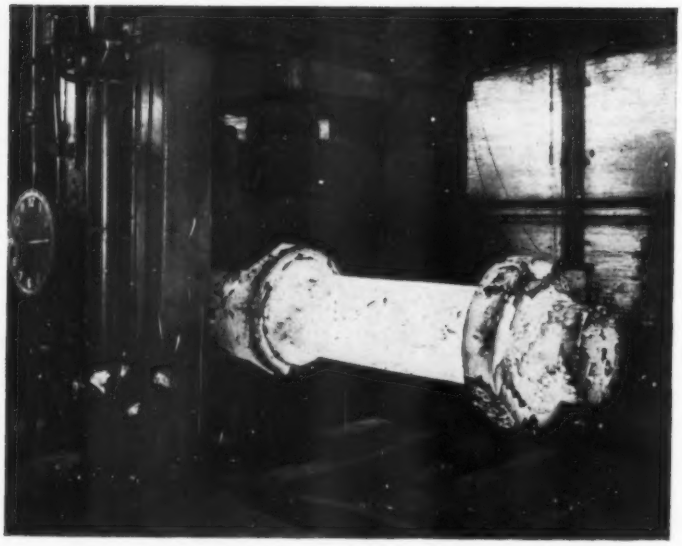
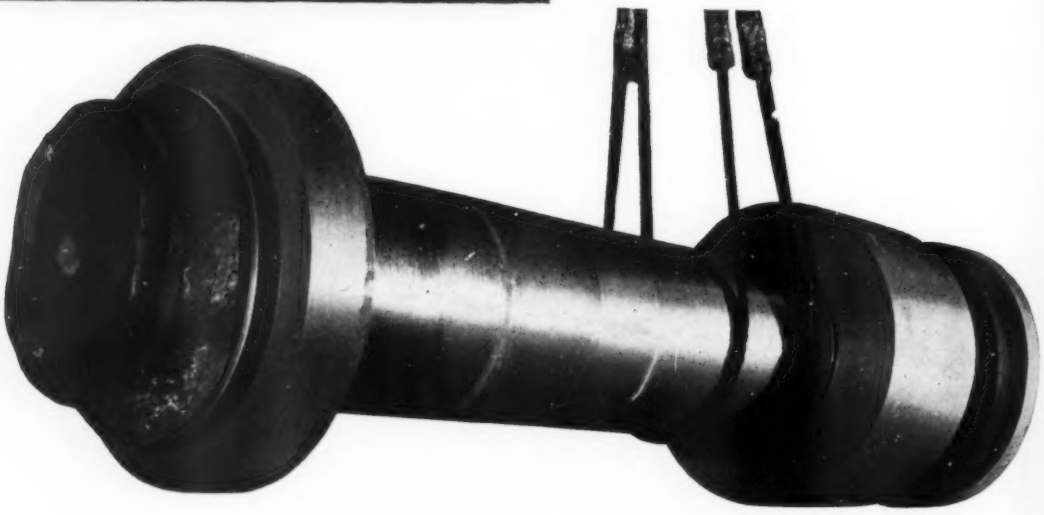


For many years ESC has been the leading supplier of steel forgings to many vital industries. Forgings in weights up to 175 tons are manufactured in our high quality carbon and alloy steels—single piece engineering units produced from ingots weighing up to 275 tons—and



other forgings from ingots 30 cwt. and upwards—for all branches of engineering.

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River Don Works, Sheffield

A wholly owned subsidiary of English Steel Corporation Ltd.

Illustrations show a forging operation under a 7,000 ton electro-hydraulic press, rough machined and black forged steel Turbine Shafts, 22′ 11″ long, 3′ 8″ diameter with 6′ 2″ and 6′ 4″ diameter couplings—weight as forged 111½ tons, rough machined 70 tons—for a modern hydro-electric power project.

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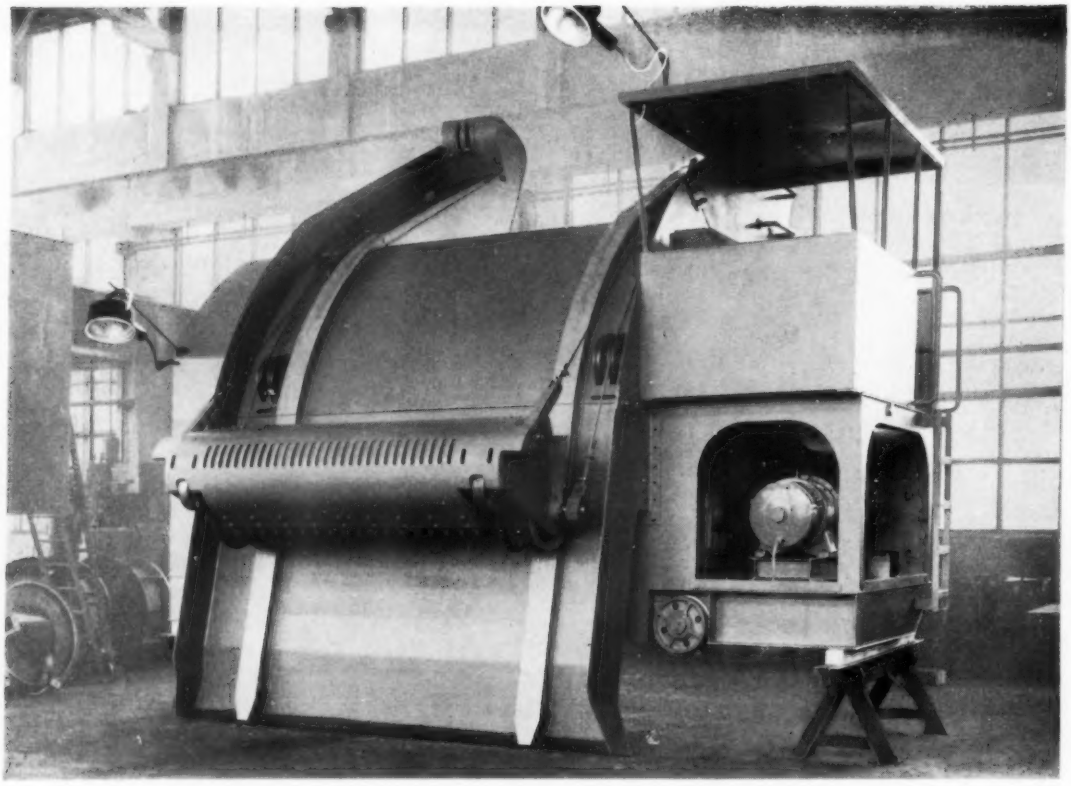
HYDRAULIC STEEL STRUCTURES



Travelling, automatic screen cleaning machine for Power Station Rio Caroni Macagua No. 1:—

Cleaning width	2.1 m
Width of rake	32 m
Travelling speed	13.5 m/min
Lifting and lowering speed	16.3 m/min

●

DESIGN AND CONSTRUCTION:

WAAGNER-BIRÓ

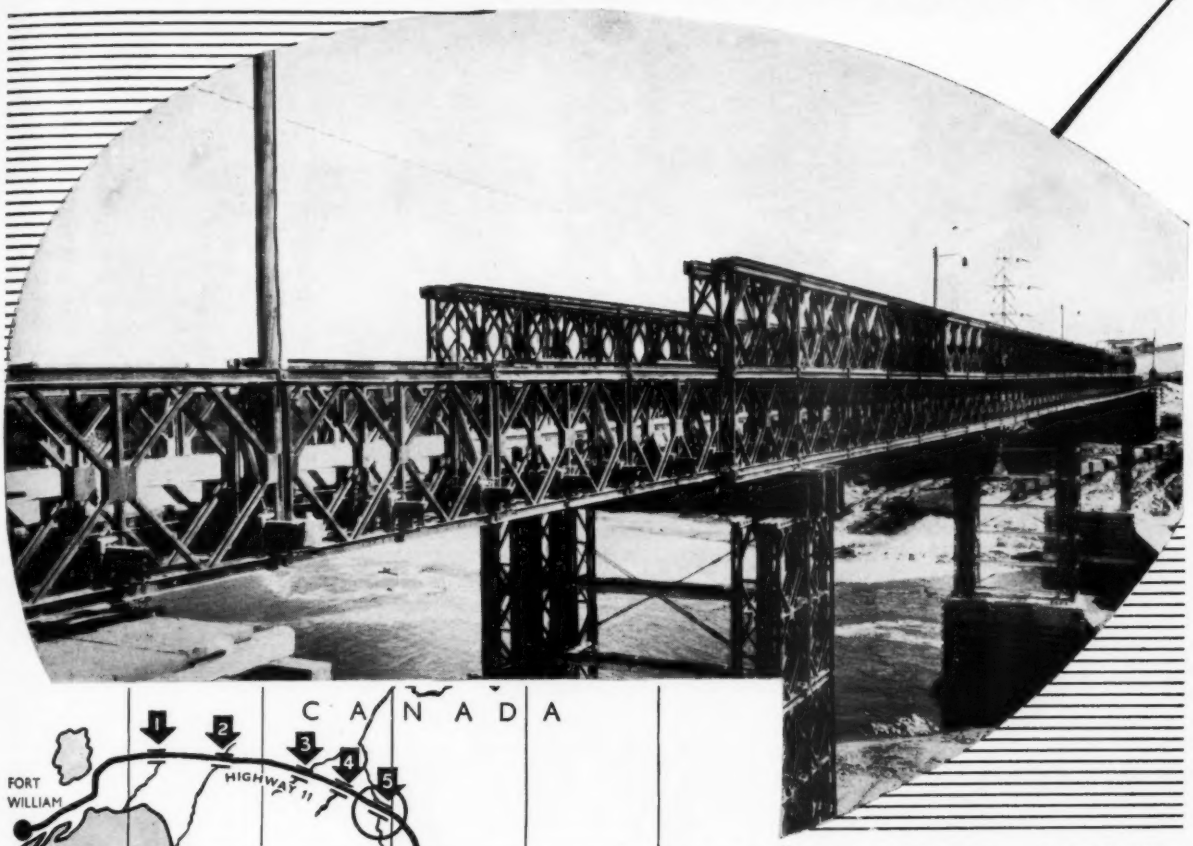
AKTIENGESELLSCHAFT

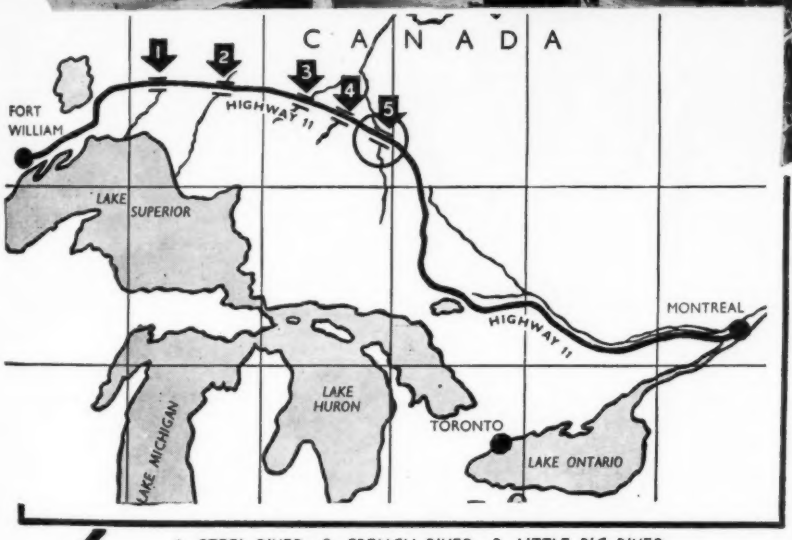
WIEN **GRAZ**

Head Office... WIEN V., MARGARETENSTRASSE 70

AUSTRIA

BAILEY BRIDGES THE GAP. . . .





1. STEEL RIVER. 2. FRENCH RIVER. 3. LITTLE PIC RIVER.
4. KAPUSKANG RIVER. 5. MATTAGAMI RIVER.

PHOTO. BY COURTESY : THE DEPARTMENT OF HIGHWAYS—ONTARIO.

The Bailey Bridge—550 ft. long—across the Mattagami River, is just one of the many in constant use by a large volume of traffic on Highway II—part of the Trans-Canada Highway.

. . . SPANNING FIVE RIVERS ON HIGHWAY II ONTARIO, CANADA

Full information on this or any other project requiring Bailey Bridging is readily available, from:

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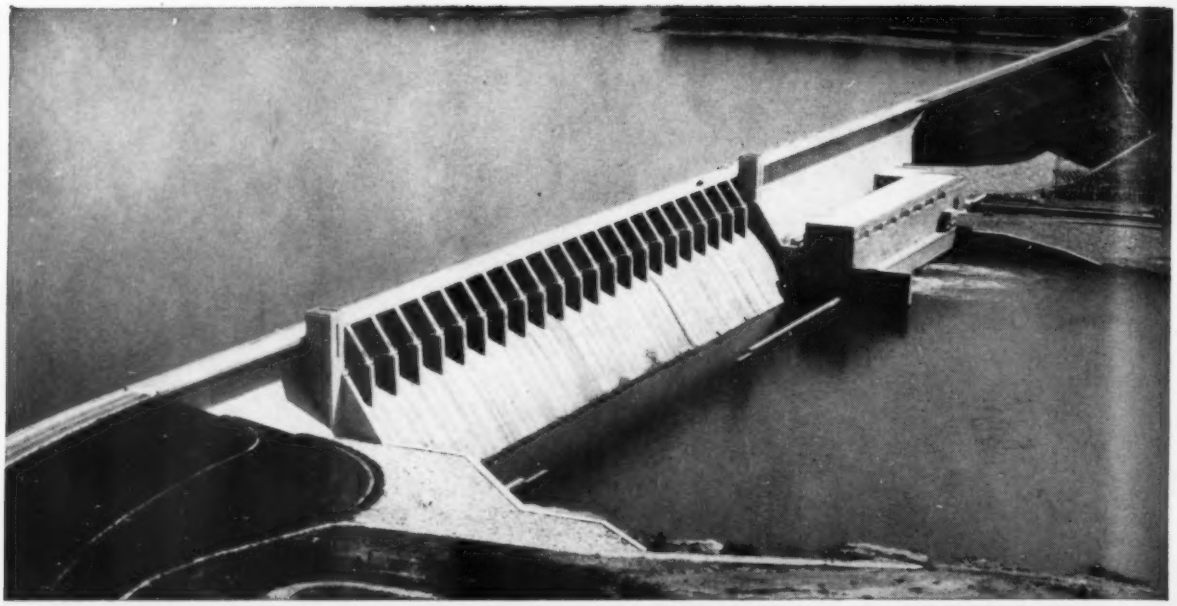
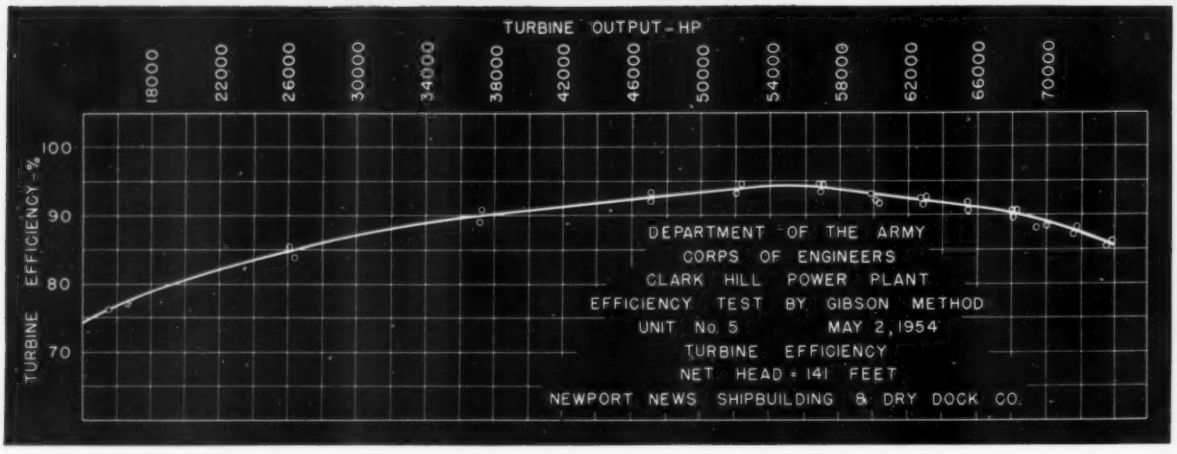




Maximum efficiency of 94.1%

Reflects advanced practices at Newport News

THE GRAPH shows performance of a 55,000 horsepower turbine, one of seven such units built by Newport News for the Clark Hill Power Plant (see photo).

Shape of the curve is typical . . . not exceptional . . . for Newport News turbine performance. Regular, uniform, showing no-cut-off at full load, it indicates consistent delivery and stable operation.

And especially, experience in design and model testing.

At Newport News, turbine runners are continually being designed and redesigned for improvements in performance. And often upon receiving a contract for turbines, a model setting is built and complete tests made. So far, Newport News has filled turbine contracts with an aggregate rated output in excess of 7,000,000 horsepower.

Penstocks, spiral casings, valves, pumps, rack rakes and other essentials are also designed and built by Newport News. Our illustrated booklet, "WATER POWER EQUIPMENT," will be sent to you upon request.

Engineers . . . Desirable positions available at Newport News for Designers and Engineers in many categories. Address inquiries to Employment Manager.

Newport News

Shipbuilding and Dry Dock Company
Newport News, Virginia

Question to Power Line Builders:

Is this your problem?

$$E_0 = \frac{4860 \times V^{\frac{2}{3}} \times m \left[{}^{10}\log \frac{2F}{kd_t} + (t-1)\,{}^{10}\log \frac{2F}{d - kd_t} \right]}{\frac{200}{kd_t} + \frac{1000(t-1)}{d - kd_t}} \text{ kV}$$

Recognise it? It's a formula for calculating the critical corona voltage when designing power lines. It is necessary to know this, since one of the chief factors determining the number and size of the conductors in a transmission line is the voltage at which power losses, due to the corona phenomenon, become serious.

The higher the voltage, the greater the difficulty from this cause—and with transmission voltages steadily rising, such problems are being met more and more. To help in solving them, Svenska Metallverken has published "Electrical Data for High Tension Power Lines," written by two of the engineers responsible for the design of Sweden's 380,000-volt power system. With its formulae, tables, and monograms, this is a handy "ready-reckoner" for use when selecting conductors for transmission lines.

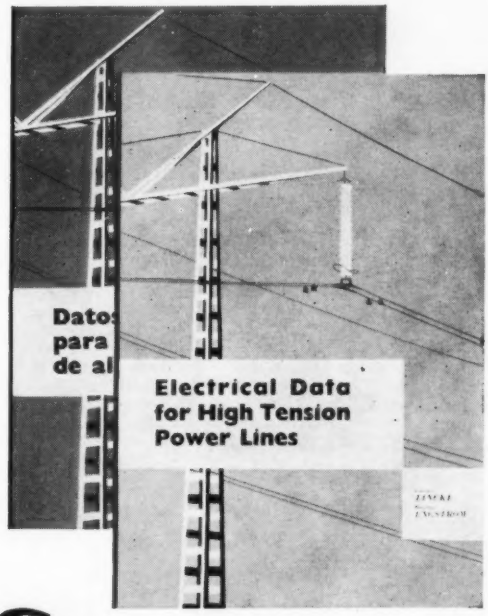
This is just one of the ways in which you can draw on Swedish technical know-how when doing business with Svenska Metallverken. Remember, too, there's a good deal of "know-how" in Feral Cable itself—the *reliable* Swedish ACSR.

When planning power lines, consult

SVENSKA METALLVERKEN

Manufacturers of Feral Cable

"Electrical Data" is available in English and Spanish editions, as well as in Swedish. When writing for your free copy, please state which language you prefer.



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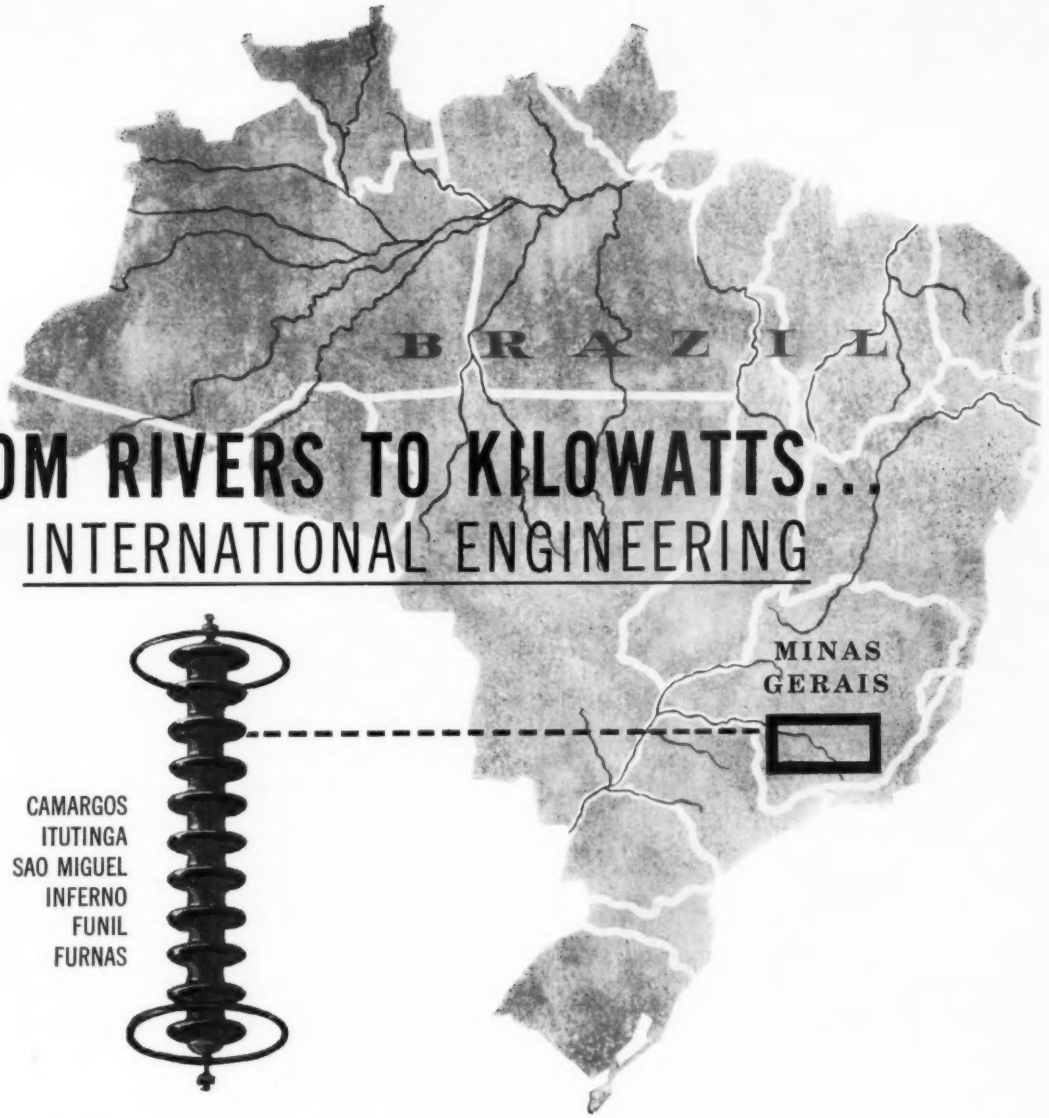

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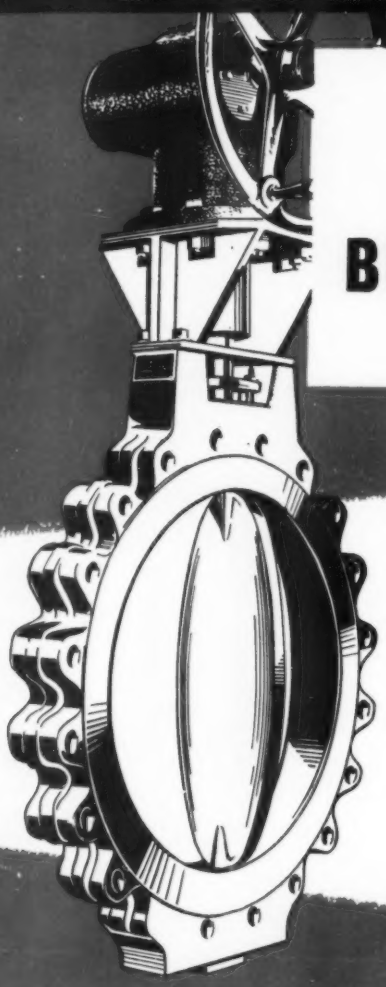

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HEAVY-DUTY
BUTTERFLY-VALVES
including WAFER-DESIGNS

Rockwell Heavy Duty Butterfly Valves are now manufactured under licence in Britain by Cockburns of Cardonald

These Valves provide wedge-tight shut off for steam, gas or fluid at pressure differential up to 150 p.s.i.

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- **Low first cost.**
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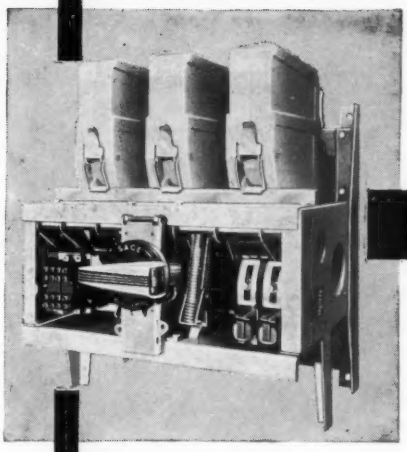
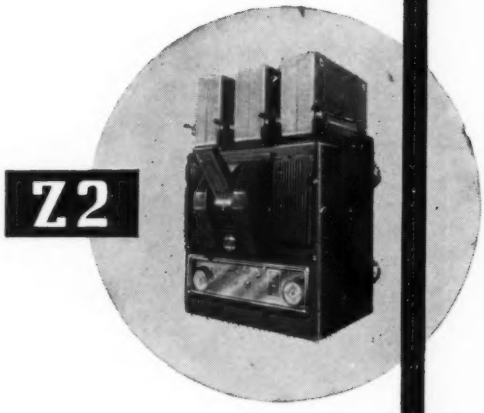
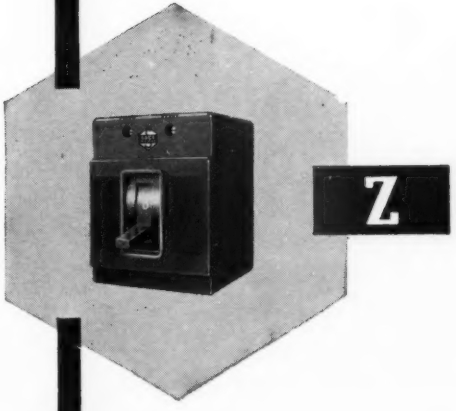
Circuit-Breaker type "P"
Rated voltage 600 V
Rated current up to 4,000 A
Breaking capacity up to 55 kA
at 500 V a.c.





Circuit-Breaker type "Z 2"
Rated voltage 600 V
Rated current up to 600 A
Breaking capacity up to 20 kA
at 500 V a.c.

Circuit-Breaker type "Z"
Rated voltage 500 V
Rated current up to 150 A
Breaking capacity up to 12 kA
at 500 V a.c.



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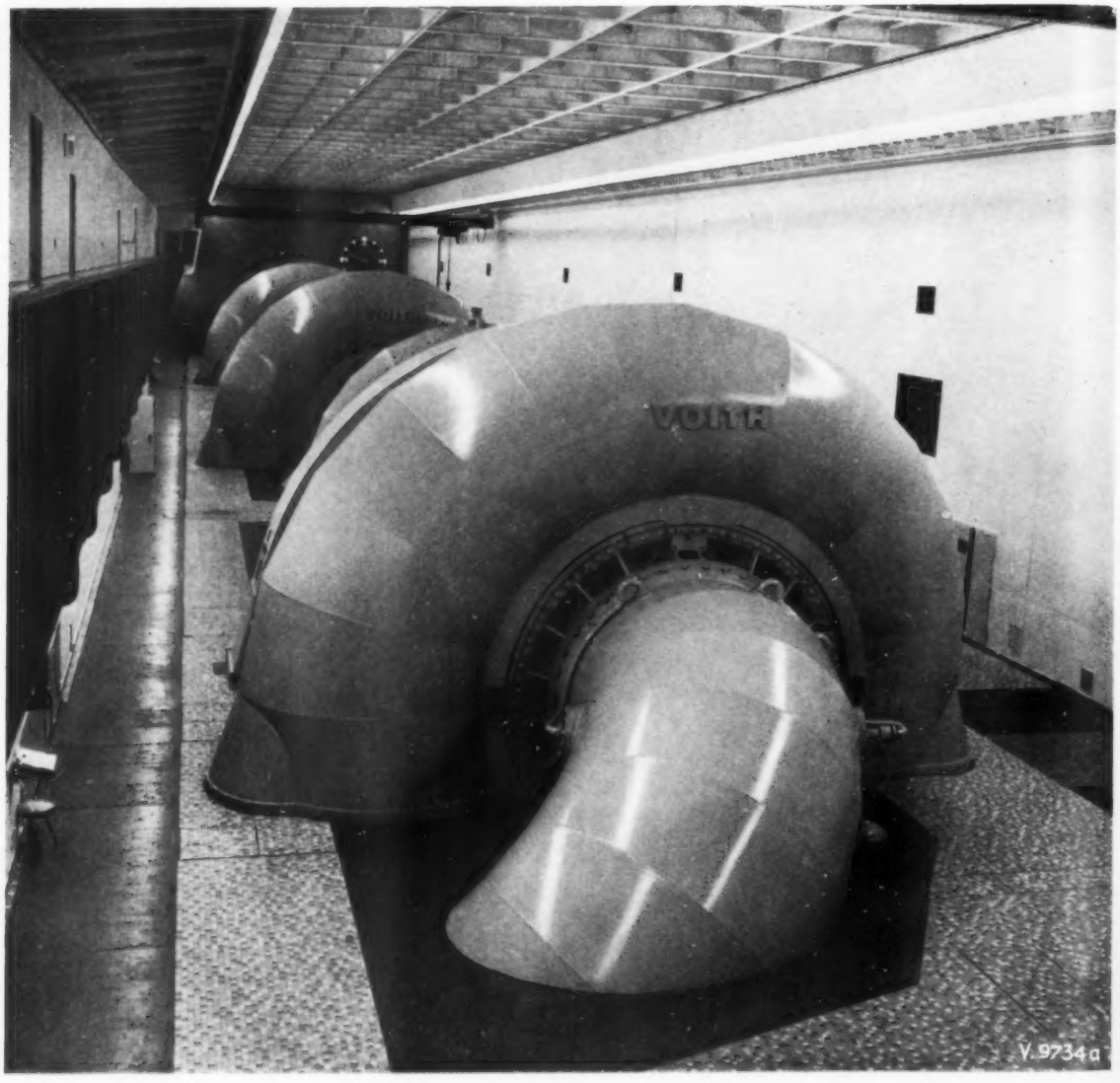
HYDRO-MECHANICAL **VOITH** EQUIPMENT FOR PUMPED-STORAGE PLANTS



3 VOITH FRANCIS SPIRAL TURBINES, each rated at 58,300 HP at 260 ft. head. installed in the GEESTHACHT PUMPED-STORAGE PLANT of the Hamburgische Electricitätswerke AG.

Voith have also designed, built and delivered for this project 3 weight-actuated butterfly valves for the intakes and 3 hydraulically operated butterfly valves ahead of the turbines, inside diameter of valves 12 ft. 6 in.

Our manufacturing programme for pumped-storage plants includes:—

Turbines of the Kaplan, Francis or Impulse type.
Storage pumps with clutches.
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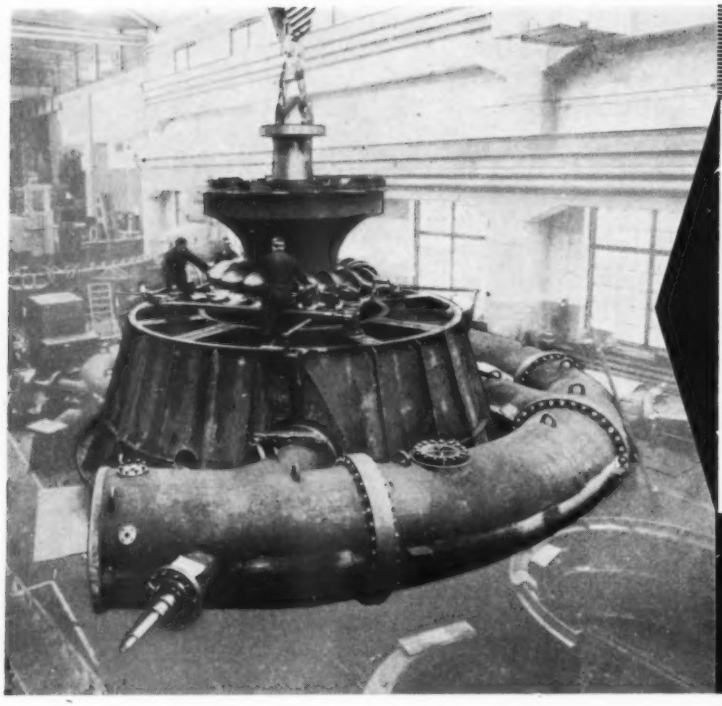

The Largest Vertical

PELTON Turbine

in Norway is a KMW Turbine

In the last half of 1958 the first of the two Pelton Turbines ordered from KMW by the Hjartdöla Power Station in Norway was put into operation; the second unit will be put into service shortly. The turbine has a nominal output of 71,000 H.P. at 555 m (1,820 ft.) net head and 428 r.p.m.

Both the turbines are equipped with the ASEA-KMW system of electro-hydraulic governing. Impulses from the electronic regulator are converted into mechanical motion in the electro-hydraulic actuator. This motion is transmitted via a separate servomotor to the deflectors and the control valves of the needle servomotors, which are linked by a conventional system of cams to provide the correct combination of controls.

This is the first time that an ASEA-KMW electro-hydraulic actuator has been used for a Pelton turbine. When the first unit was started up and put into service, the regulating system operated perfectly without any adjustment. Alterations in speed when throwing-off load were very small and the return to normal revolutions was remarkably quick.

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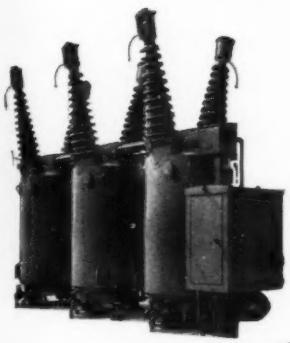
KMW

5000 MVA

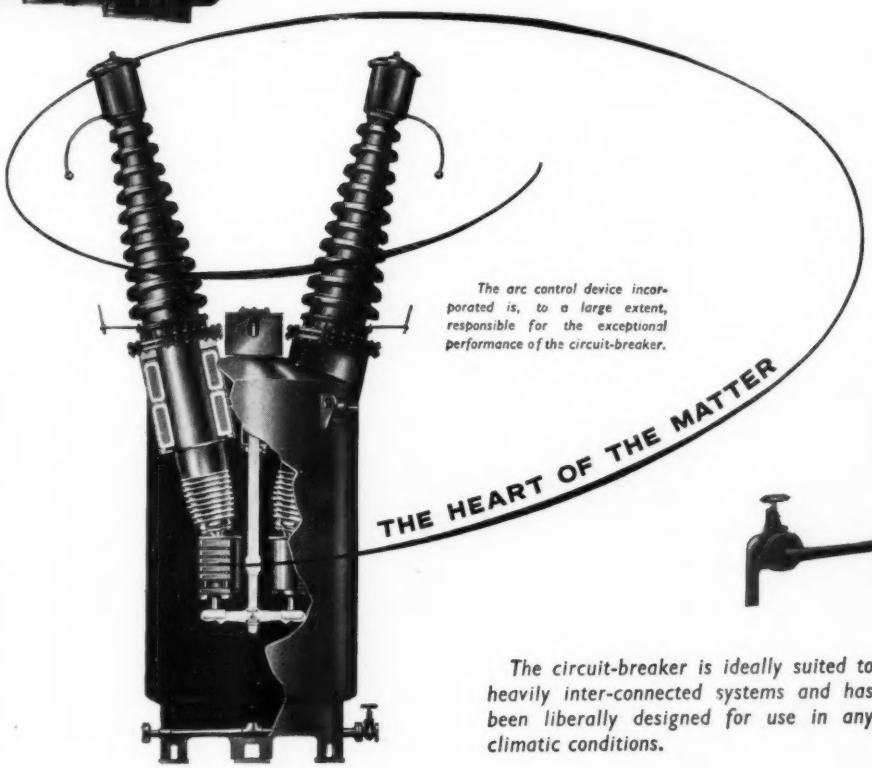
Performance

at 132 kV, 3-phase, 50 cycles



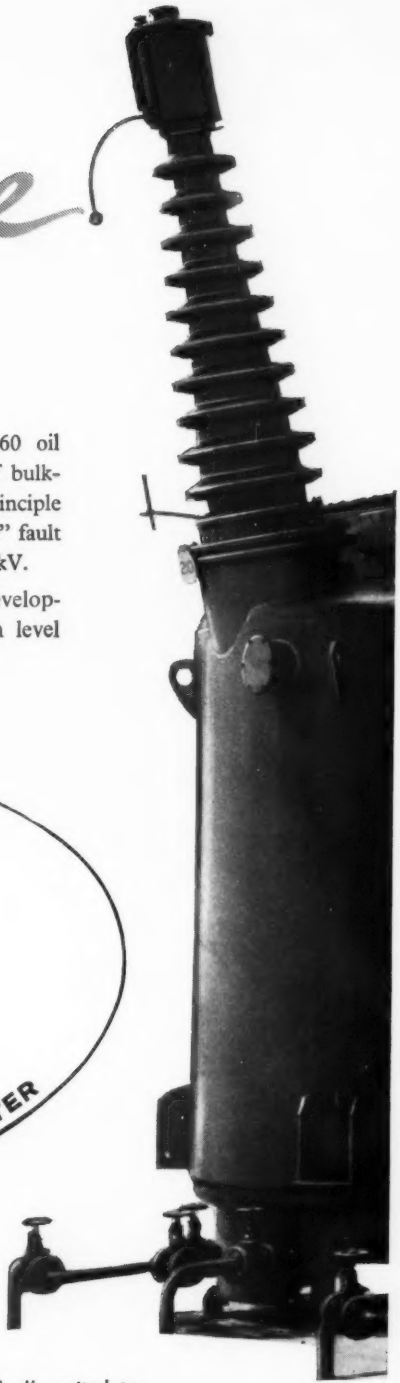
The "FERGUSON PAILIN" Type XOPR60 oil circuit-breaker is outstanding in the field of bulk-oil circuit-breaker design, inasmuch as its principle feature is a *proved* ability to interrupt and "make" fault currents equivalent to 5 000 MVA at 132kV.

In line with "FP" activities in switchgear development generally, this represents a high level of achievement.



The arc control device incorporated is, to a large extent, responsible for the exceptional performance of the circuit-breaker.

THE HEART OF THE MATTER



The circuit-breaker is ideally suited to heavily inter-connected systems and has been liberally designed for use in any climatic conditions.

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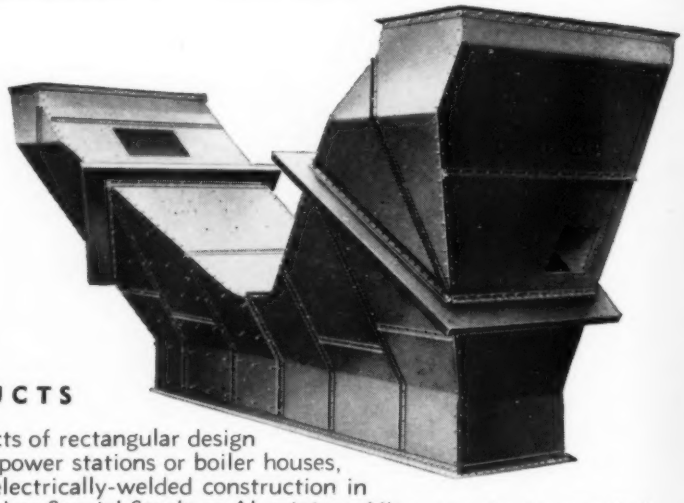

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Ducts of rectangular design for power stations or boiler houses, of electrically-welded construction in Mild or Special Steels or Aluminium Alloy, can also be supplied. They are accurately fabricated to suit your exact requirements.

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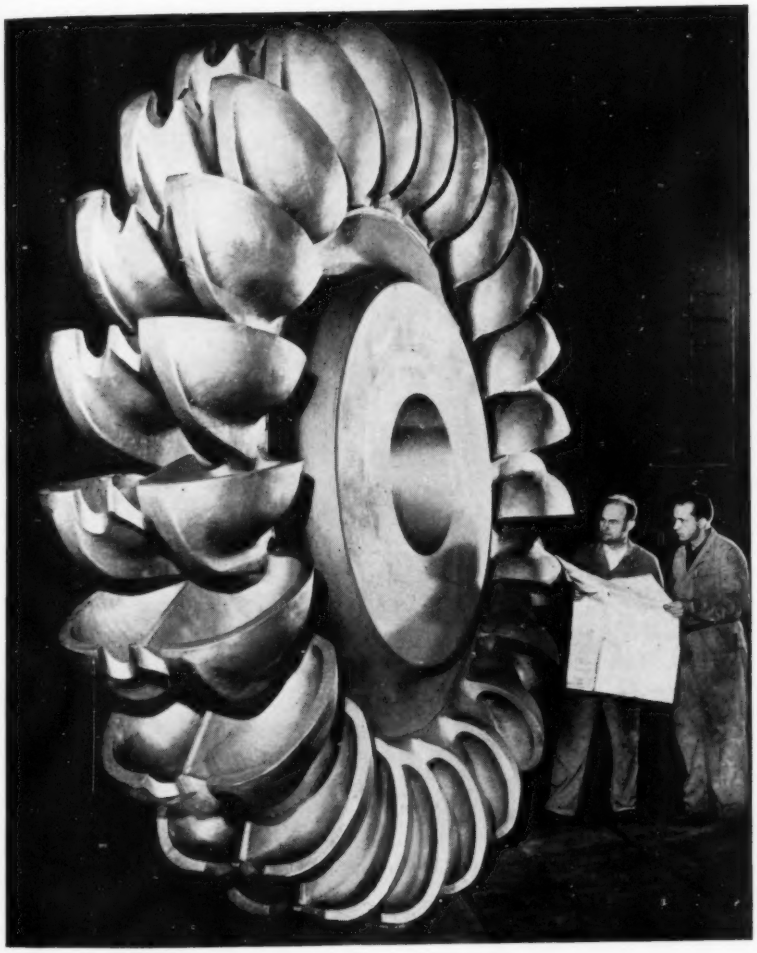

Wheel of one of the two PELTON units

Output each:-
107,000 kW.

Available head:-
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Discharge:-
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Speed:-
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EUROPE'S HIGHEST OUTPUT PER UNIT

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The outdoor switchgear at Jog Falls Power Station, in Mysore State, India, equipped with S.P.P. Cylindrical Post Insulators type P.701.

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Serre-Ponçon Dam Project : concrete gallery extending over 7,000 ft.

Laksapana Power Plant : Two 16,100 kW Pelton units under erection

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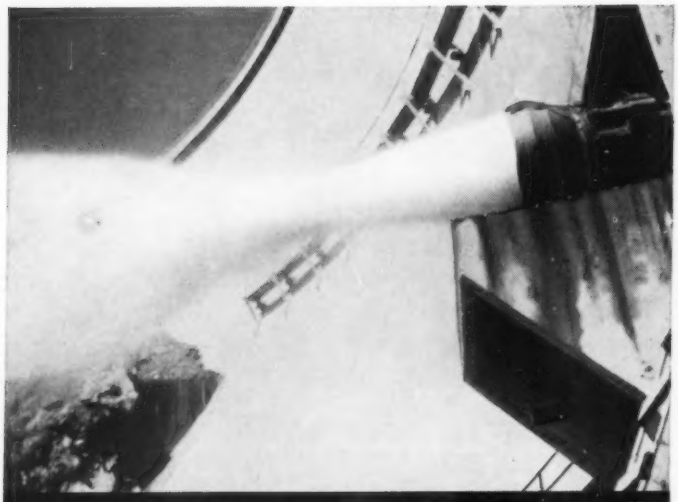
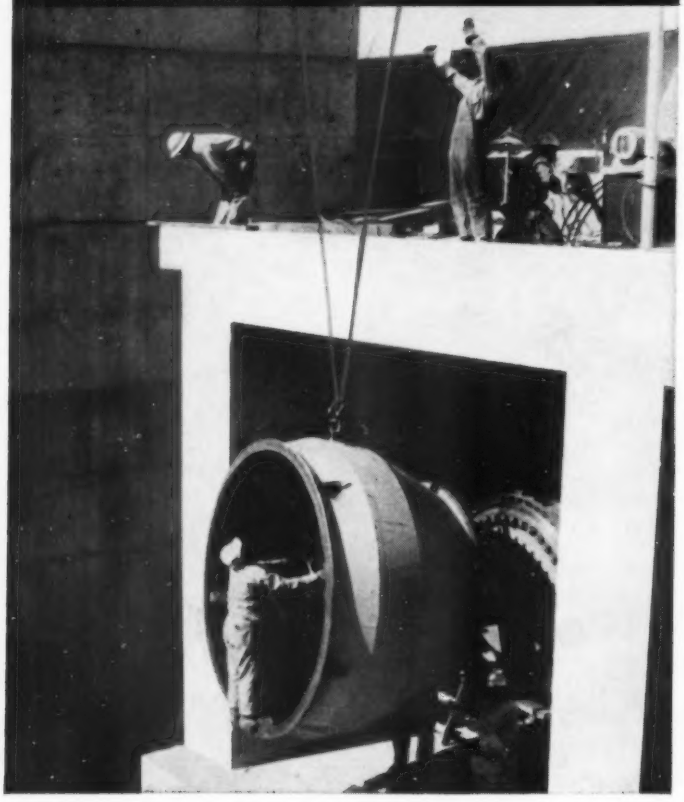


This 18-inch Ring-Jet Valve, installed by the City of Bremerton, Washington, is manually operated. Under a 115-foot design head, it discharges 76 MGD when fully opened. Note how the hood concentrates the discharge stream.

One of two 66-inch A-C Ring-Jet Valves during final assembly at Tulloch Dam, California. These valves are used for an irrigation bypass, operate under a 145-foot head.



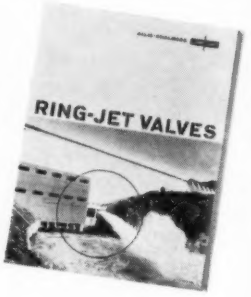
RING-JET VALVES

for easy regulation and control of water under free discharge

Allis-Chalmers Ring-Jet Valves are a logical development from the Howell-Bunger Valve. For use under high- and low-head, free-discharge conditions, the A-C Howell-Bunger creates a substantial amount of spray in providing maximum dispersion to minimize erosion. Now, in the A-C Ring-Jet Valve, the addition of a steel hood creates a concentrated jet, reduces spray, and helps dissipate the energy in the discharged water.

This new A-C Ring-Jet Valve gives you the simple construction, radially-balanced hydraulic design and easy operation of the A-C Howell-Bunger Valve, while very nearly matching its high discharge coefficient. Ring-Jet Valves are available with standard manual and/or motor-driven operators. Hydraulic operation can be provided, and is especially applicable to the larger sizes and higher head applications.

To obtain complete information on the A-C Ring-Jet Valve, contact your nearest Allis-Chalmers office, or write Allis-Chalmers, Hydraulic Division, York, Penna.



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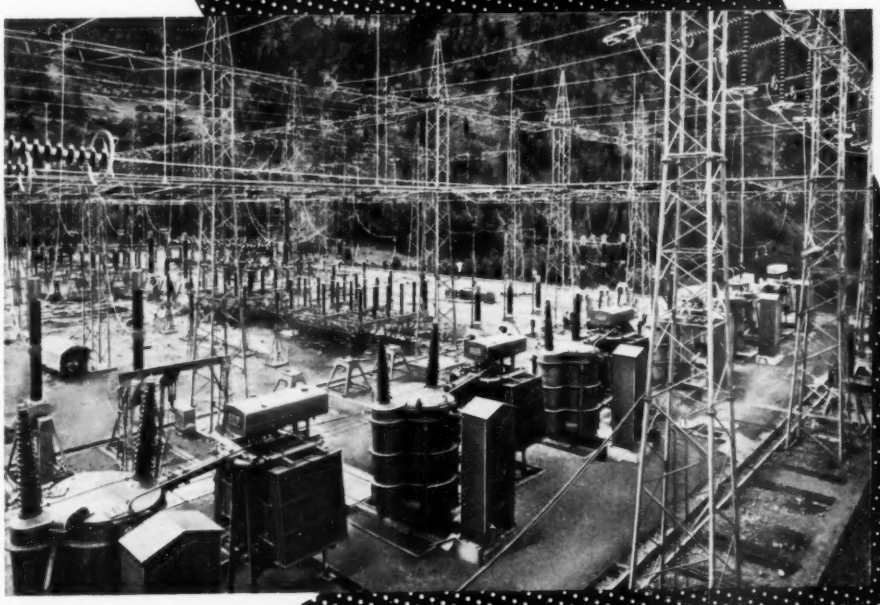

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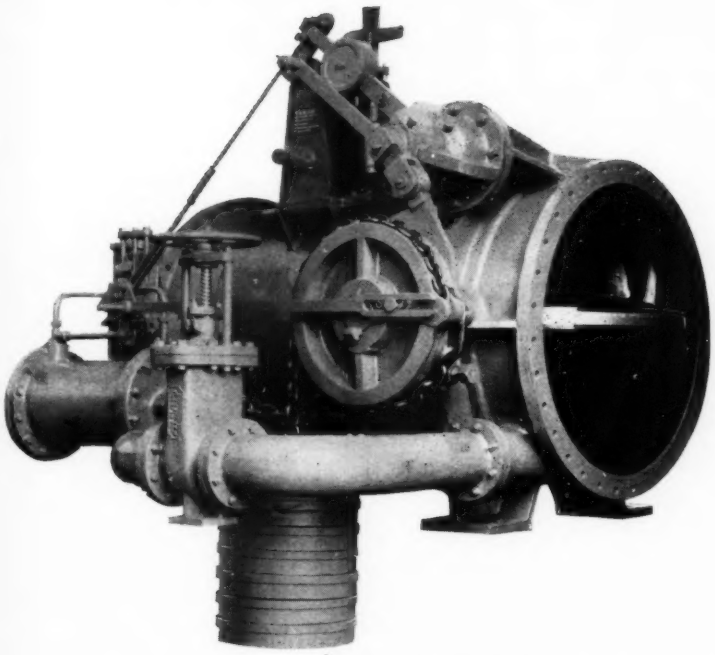

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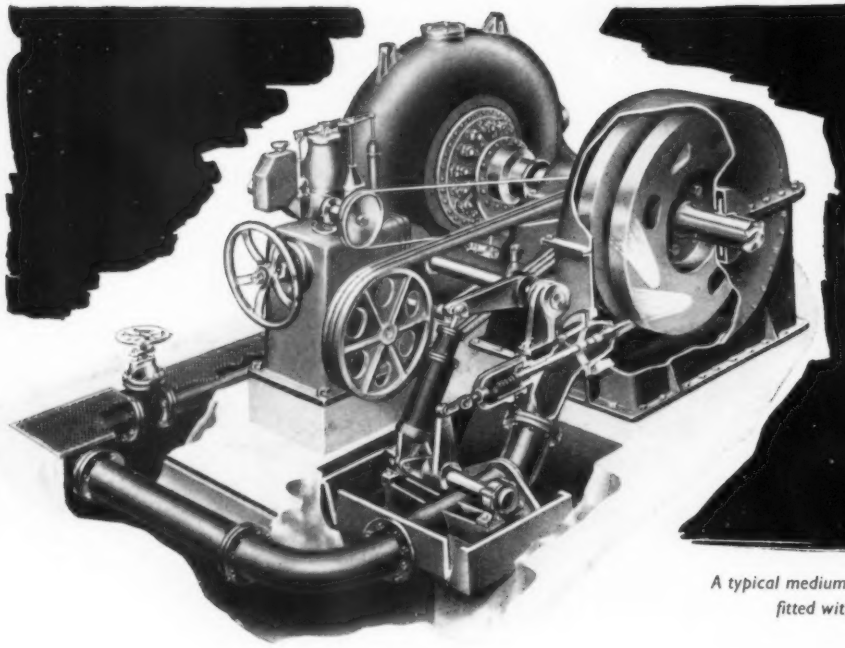

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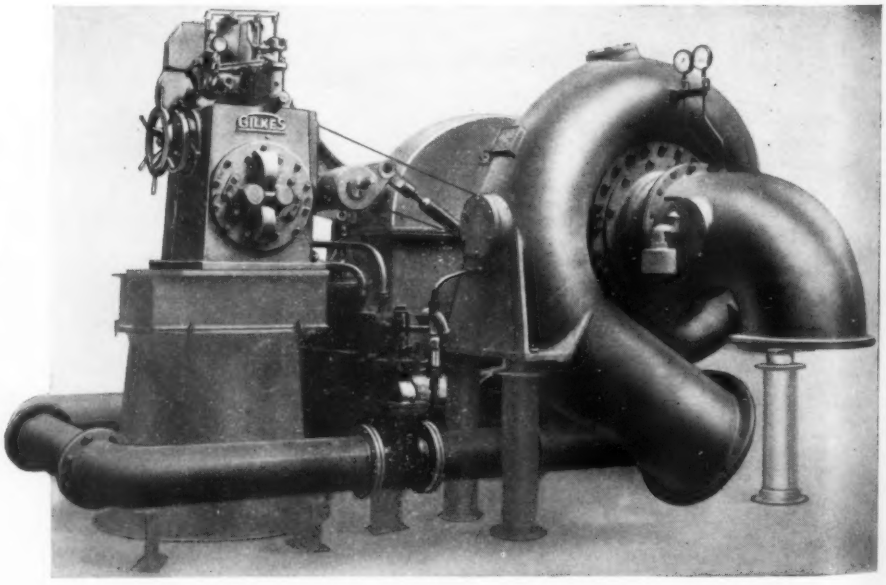
A 3,100 horsepower 'Gilkes' Francis turbine operating on 340 feet head and fitted with GILJET governing. This unit is installed in the North of Scotland Hydro-Electric Board's Kilmelfort Power Station. The pipeline is 4,700 feet long and there is no surge chamber.



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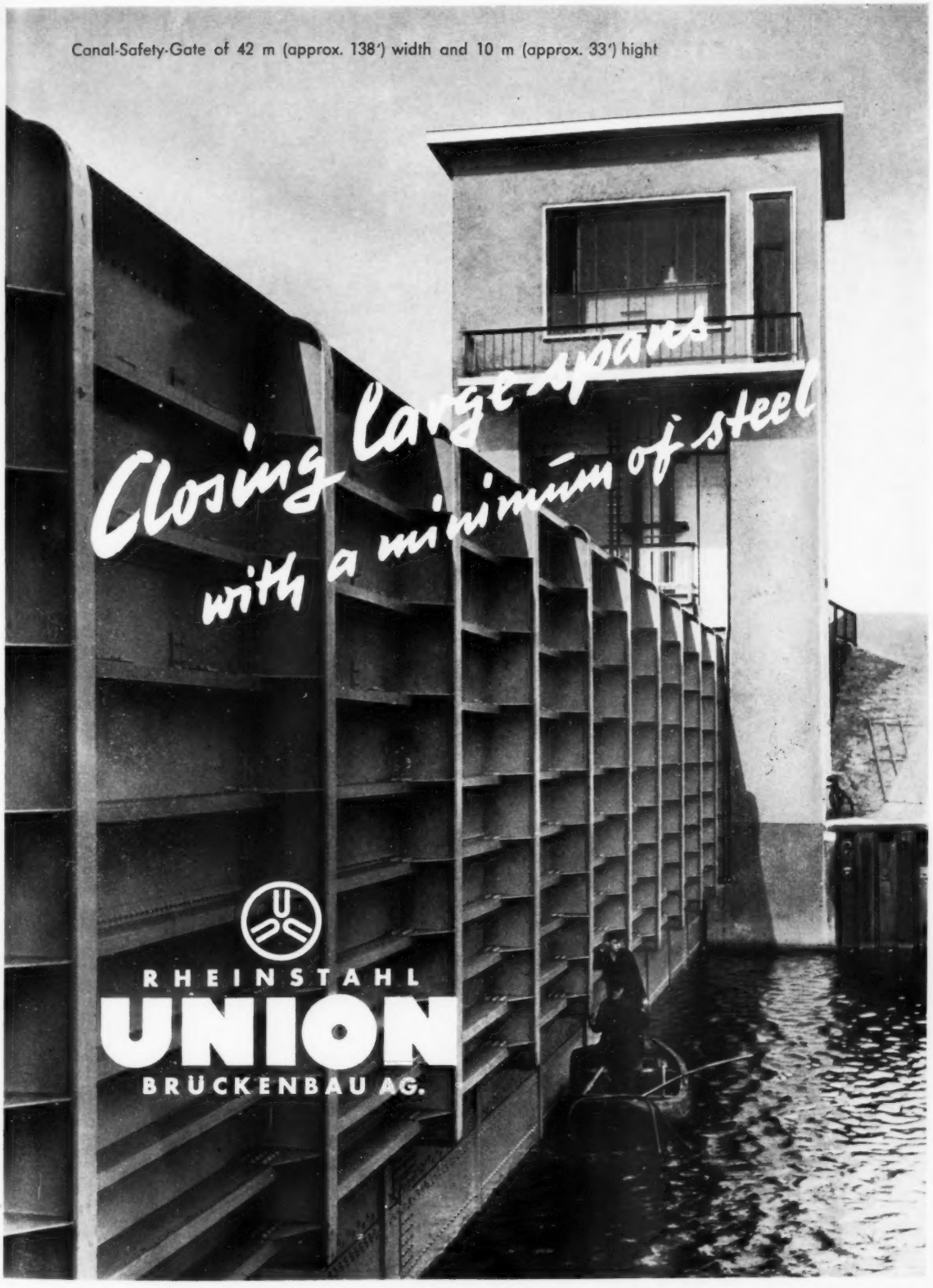
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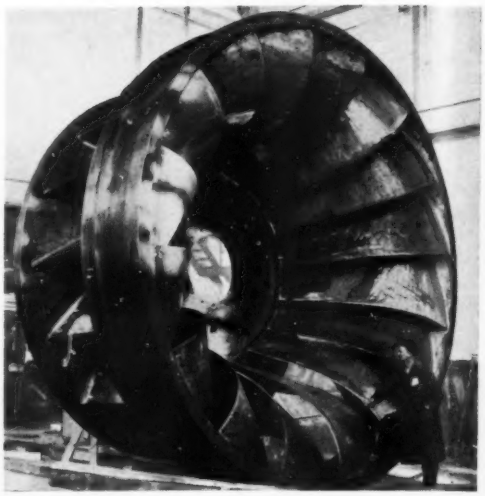
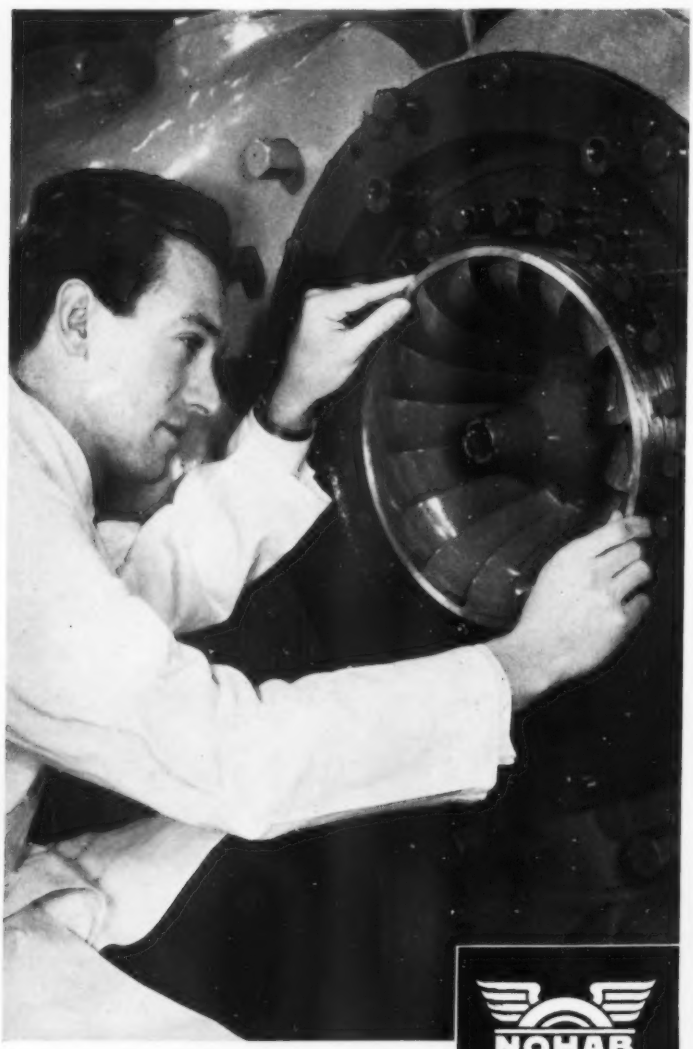
NOHAB awarded turbine contract for the Furnas Power Station

In the face of keen competition between the most known turbine manufacturers in the world, NOHAB recently received the order for four Francis turbines for the Furnas Power Station, Brazil. These turbines will have a maximum output of approximately 225,000 HP each, under a net head of 98.7 m (323 ft. 11 in.). They will be similar to those already delivered by NOHAB to the Swedish State Power Board for their Stornorrfors Power Station.



Above: *One of the runners for the Stornorrfors Power Station, Sweden. Each runner has a guaranteed maximum output of 200,000 HP under a net head of 75 m (246 ft.).*



Left: *A model runner of the Francis type to be tested in NOHAB's hydraulic laboratory.*

Below: *One of the runners for the Lasele Power Station, Sweden. Each runner develops 87,200 HP under a net head of 52 m (170 ft.). This head is the highest in Sweden for which Kaplan turbines have been built.*

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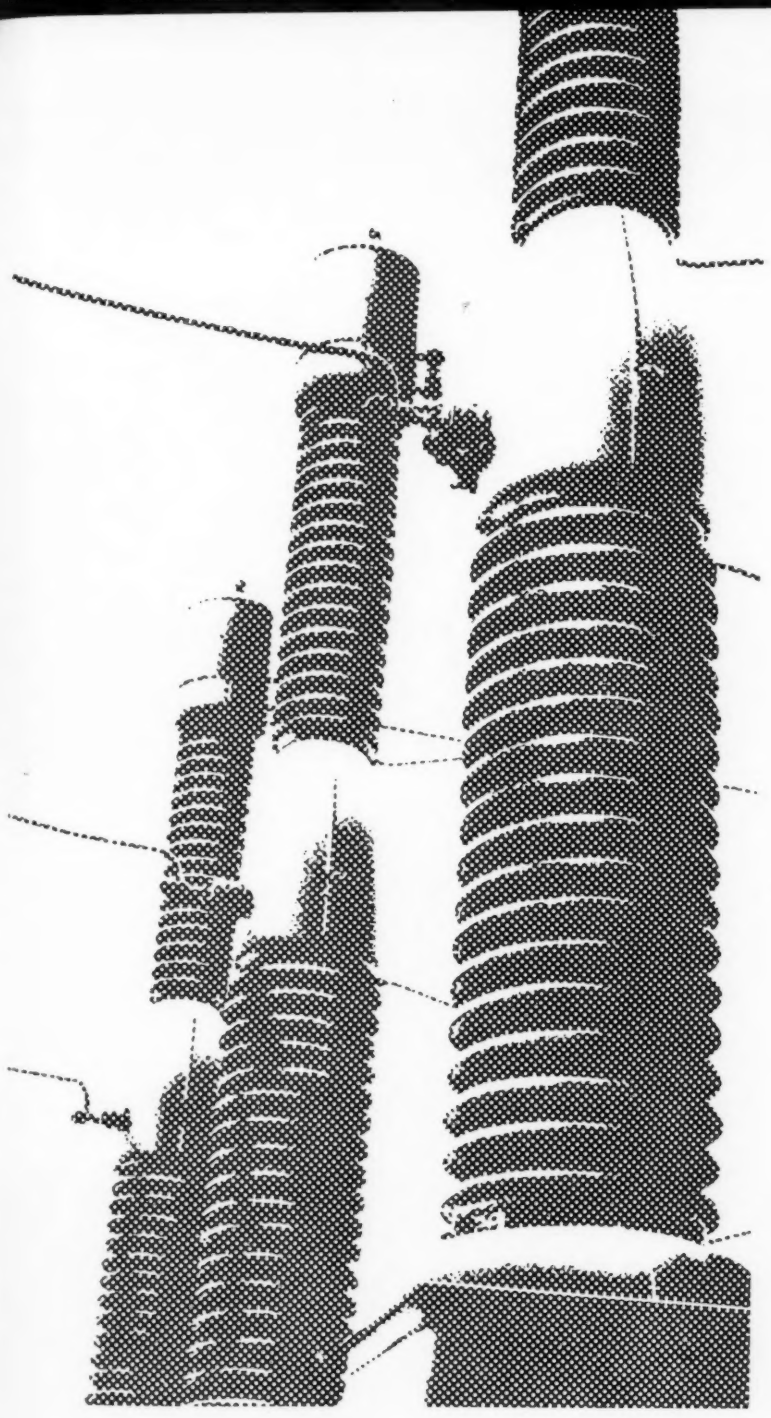

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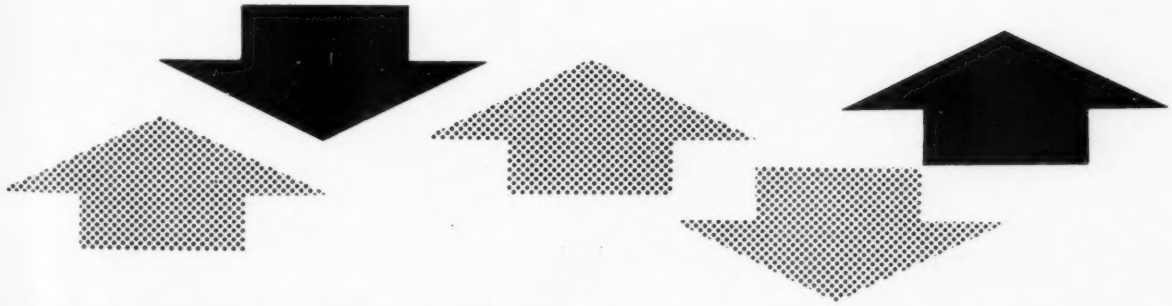

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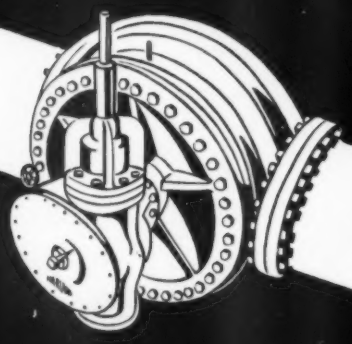

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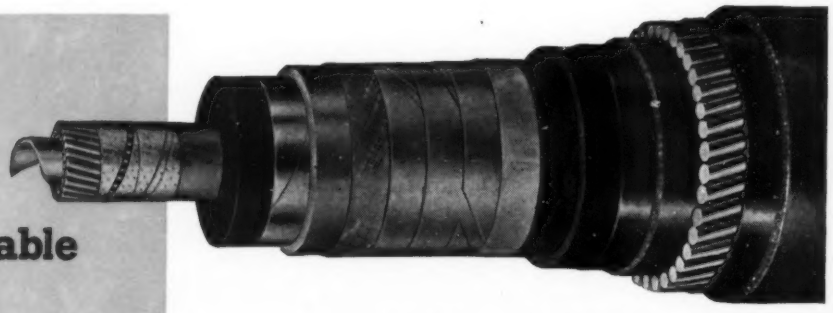

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The Small Hydro Plant

FOR some years a Working Party of the United Nations Economic Commission for Europe has been studying rural electrification, and one of the subjects in which this Working Party has been interested is the role of the small hydro plant. In the Economic Commission's first Report on Rural Electrification a study was made of "micro" water-power plants—by which was meant installations up to about 100 kW—and we discussed its findings under this head at length in our Leading Editorial in our July 1954 issue.

In the third Report*, which has recently been made available, a return is made to the subject in a report by Monsieur Ch. Crescent on the principles governing the use of smaller hydro plants in local networks and main grids. In this report the net is cast rather more widely, as the upper limit of size is taken at 1,000 kW, and the findings of the report are based on a survey of small water-power plants in various European countries. Some of these surveys are of definite interest, but in some cases they refer to periods so long past that to draw conclusions from them as to current trends, in our view, is of questionable value.

The most recent figures come from France and relate to 1954, when there were 374 stations in service with individual capacities below 100 kW and 17 with capacities between 100 and 1,000 kW, the total installed capacity being 8,542 kVA and the total production 24·25 GWh. These plants represented only one-thousandth of the total hydro-electric capacity installed in France at that time, but this low figure does not imply the disappearance of the low-power station; on the contrary the number of these stations increased steadily from 249 in 1930 to 391 in 1954.

In Czechoslovakia in 1953 stations below 200 kW capacity numbered 5,291 and represented more than 95% of the total number of hydro stations, but their aggregate capacity, of 99,585 kW, amounted to less than 22% of the total for the country.

In 1952 in the Würtemburg district of the Federal Republic of Germany, 14 hydro stations with an aggregate capacity of 13,000 kW were situated on small rivers under heads in most cases less than 10 m., and produced 37 million kWh. About 50 small stations were to be connected to the system within five years.

Data for Switzerland are given for the years 1936, 1942 and 1948. The number of stations with a capacity of less than 100 kW decreased from 151 in 1936 to 135 in 1948, and the total capacity from 9,240 kW to 6,825 kW, but the number of stations between 100 and 1,000 kW rose from 77 to 86, the capacity increasing from 55,500 to 61,700 kW.

The period covered by the data for Italy is not quoted, but the installed capacity of low-power plants is given as 212,700 kW, furnished by 714 stations of less than 100 kW capacity and 414 stations between 100 and 1,000 kW. This represents 2·5% of the total Italian hydro capacity.

Figures for Sweden relate to 1 January 1933, when, out of a total of 1,313 hydro stations 1,068 were small ones aggregating 227,726 kW. On 1 January 1935, the total installed hydro capacity in Sweden was 3,516,741 kW. These figures obviously give little guide as to the trend in Sweden at the present moment, but apparently about ten plants in the 100–1,000 kW range were placed in service during 1953–54.

Data for the United Kingdom were provided by the North of Scotland Hydro-Electric Board, who maintain four small stations aggregating 1,265 kW on the mainland and a few others in the islands. These figures, however, do not give a complete picture, as most of the small hydro stations in the British Isles happen to lie outside the North of Scotland Hydro-Electric Board's area.

In the Soviet Union small stations run into thousands and play an important part in rural electrification.

Monsieur Crescent concludes from his study that small hydro plants are making an effective contribu-

* "Rural Electrification," Volume III, European Office of the United Nations, Palais des Nations, Geneva. Sales Number 58.II.E/Mim.9. Price $1·50 (U.S.); 11s. stg.; 6·50 Sw. Fr.

tion to the electric power supply of the countries consulted, albeit on a small scale. They are usually located at a distance from large centres of population and their main function is to improve rural distribution. Monsieur Crescent points out a most interesting similarity between the relation to total national installed capacity of small hydro plants and of international power exchanges. This similarity between two sources situated, so to speak, at opposite ends of the scale, would appear to indicate that even relatively small amounts of extra power are useful in the operation of systems.

With small hydro plants the question of capital costs becomes very important, and the value of a low-head low-power site may be transformed if it is possible to make use of existing engineering works such as an old lock. In French opinion sites offering less than 50 kW are not profitable unless conditions are very favourable.

The mechanical and electrical equipment, also, has an important bearing on the cost and on the amount of attention required, and perhaps the most useful section of Monsieur Crescent's report is the summary —too lengthy to be given here—of the various ideas, many of which are conflicting, about turbine governing, the use of synchronous or induction generators, voltage control and regulation, and switching, electrical control and safety gear.

Monsieur Crescent's report, which sums up in favour of the future of the small hydro plant, has avowedly been written from the standpoint of their connection to public-supply systems, and although mention is made of the independent plant little information is presented as to its prospects. The main difficulty, of course, is to collect reliable and sufficiently comprehensive data about independent plants, but they must obviously exist in large numbers. The papermill power plant which we described in our November 1958 issue is typical of the small industrial plant, and other articles in our past issues have borne testimony to the interest taken in the development of "micro" sets for estate duty. A survey of the field for the independent plant would be difficult to carry out but would be absorbingly interesting.

Norwegian Hydro-electric Power Projects

NEW hydro-electric power projects, to cost 428·8 million kroner (£21,440,000), are outlined in a government bill submitted to the Norwegian Parliament recently. It is assumed that substantial loans for financing these projects will be made available by Swedish sources and the World Bank. The total capacity of Norwegian power plants was increased by 540,000 kW last year. New generators, due to be installed this year, will add over 600,000 kW.

The latest government bill requests Parliamentary approval of plans for a new power scheme in the province of North Tröndelag and a long-distance, high-voltage transmission line to link Tröndelag with the East Norway power grid. The State and North Tröndelag would each finance half of the 233 million kroner (£11,650,000) cost of the large Tunnsjö development project. All expenses in connection with the power transmission line would be borne by the State. Development of Lake Tunnsjö and its waterways is estimated to yield an annual power production of some 1,130 million kWh. Subject to Parliamentary approval, the plan calls for exporting part of the output to Sweden—300 million kWh annually for 20 years and 150 million for a shorter term, with possibility of increasing the export by an additional 100 million kWh. The proposed transmission line would link the Tunnsjö, Nea and Aura power plants with Vinstra, which already is connected with East Norway.

Supplementary funds for three other power development projects are included in proposals for the 1959–60 State Budget. One hundred million kroner (£5 million) is requested for the large Tokke project, which eventually will have a capacity of 800,000 kW. The 90,000 kW Innset power plant in the province of Troms, has been earmarked for an additional 20 million kroner (£1 million), and 31·2 million kroner (£1,560,000) would go to develop Upper Rössåga river, in Nordland, to supply more power to MOSAL aluminium plant and the Norwegian State iron works.

New Snowy Mountains Power Line

WORK will begin before the Australian winter on a major high-voltage transmission line to feed power from the Snowy Mountains and the Tallawarra power station into the State-wide electricity network. Tenders for the line, which will run 42 miles from Dapto to the site of a big new sub-transmission station south of Sydney near Revesby, closed in April. The transmission line, carried by more than 200 steel towers, each 100 ft. high, is a top-priority project and will be completed early in 1960.

At Tallawarra a 100 MW generator now being built in Britain will be in service, raising the station's output next year to 220 MW. The capacity of the Snowy Mountains T1 hydro-electric station at Cabramurra will be increased next year to more than 200 MW, and this winter the first output of T1 power, having a capacity of over 100 MW, will be received by the Electricity Commission.

The new Dapto-Sydney line, to operate at 132 kV for the first two years, will be the third 132 kV circuit to come into service between Tallawarra and Sydney. At the end of 1961 the line will be energised at 330 kV to feed into the new £2 million Sydney South Substation near Revesby, on which work will begin in a few months. The construction of a five-mile steel tower transmission line from the site of this new substation to Bankstown will also begin this year. This line will be operated at 132 kV.

British Columbia Power Corporation

THE British Columbia Power Corporation Limited has published its annual report for the year 1958 showing that revenue was $8,876,483 or $1·95 per share on the common shares outstanding at the end of the year as compared with $9,582,598 or $2·33 per share for 1957 on a lesser number of outstanding shares; the quarterly dividend rate of 35 cents was continued.

The Western Development and Power Limited, a wholly-owned subsidiary of the Power Corporation, was originally formed in 1956 with the principal aim of investigating the hydro-electric potential of the Fraser River. This investigation has now begun but it will be some time before power from the Fraser will be available. Little was known of the power potential

of the Peace River in north-east British Columbia until preliminary surveys conducted by the Wenner-Gren organisation during 1957 and 1958 indicated that not less than 3,000,000 kW could be produced there economically (see WATER POWER, July 1958, page 244). The Western Development and Power Limited has purchased an interest in a new company which is carrying out further investigations to establish, before 31 December 1959, more accurate costs of generating and transmitting Peace River power.

At present, estimates of power requirements indicate that, by 1978, British Columbia will need practically all the power from both the Peace and Columbia rivers. Development of the upper Columbia requires agreement on several problems between Canada and the United States before an approach can be made to the provincial and federal authorities concerned, and it is impossible to predict at this stage when and how Columbia power will be available.

The Power Corporation is now investigating all possible sources of power, including nuclear generation. It is hoped that a start may be made soon on one or more of the major rivers because the large hydro-electric resources promise the cheapest power and their development would be an excellent stimulus to the economical development of British Columbia.

Plant Orders for Remaining Strathfarrar and Kilmorack Stations

THE North of Scotland Hydro-Electric Board have placed contracts for the generating plant for the remaining two power stations of their Strathfarrar and Kilmorack scheme in Inverness-shire, referred to in our May issue. The English Electric Co. Ltd. have been awarded the contract for the generating plant at the Culligran power station in lower Glen Strathfarrar. The plant in this station, which will consist of a 30,500 h.p. Kaplan turbine driving a 22,000 kW generator, will be made at Harland & Wolff's Scotstoun engineering works, Glasgow. At the Deanie power station, six miles farther up the Glen, the plant will consist of two 26,600 h.p. vertical-shaft Francis turbines each driving a 19,000 kW generator. The contract to manufacture and supply these sets has been placed with the English Electric Co. Ltd. who will manufacture the generators at Scotstoun while the turbines will be made by the Harland Engineering Company, Alloa, as subcontractors.

The electrical and mechanical consultants for the Strathfarrar & Kilmorack Scheme are Messrs. Kennedy & Donkin, Edinburgh.

Picote Station Inaugurated

PICOTE station, the first Portuguese hydro-electric plant on the international stretch of the river Douro, which was described in our April and May issues, was officially inaugurated on April 19 by the President of the Portuguese Republic, Admiral Américo Thomaz, in the presence of a number of ministers and Portuguese and Spanish official personages. This station, which has an installed capacity of 180 MW, will produce 1,000 GWh in an average year on a run-of-the-river basis. Its cost was approximately £8,400,000.

The Hidro-Eléctrica do Douro, the society entrusted with the development of this river, is now building the Miranda plant, which will have an installed capacity of 156 MW and an average output of 785 GWh. This site was also visited by the President of the Republic.

The access roads to Bemposta, the last station to be erected on the Portuguese section of the international stretch of the Douro, are already under construction. This station is expected to have an installed capacity of 210 MW and a mean annual production of 950 GWh.

Correspondence

Picote Station

To the Editor, WATER POWER

I have just received the April 1959 issue of WATER POWER and noted the excellent article on the development of the Douro River in Portugal.

The Portuguese should not be denied any credit for their contributions to hydro-electric engineering and particularly to their original work in the field of arch dam design. However, in planning for the development of the Douro River and particularly in pointing out the great undeveloped power potential of the International Douro some mention should be made of the comprehensive engineering and economic study undertaken by Knappen-Tippetts-Abbett-McCarthy (now Tippetts-Abbett-McCarthy-Stratton), consulting engineers of New York, in the years 1951–53. Other internationally known experts in the field of power economics, dam design and geology collaborated with the regular staff of the engineers on the study. The final report involved a power market study of the entire country as well as a plan for the development of the Douro. The Portuguese government at that time was only interested in initiating work in the lower river, entirely within Portugal, and had overlooked the more economical projects possible on the International Douro. Although a treaty existed which provided for mutual developments along the international boundary, historical difficulties with Spain and outmoded concepts of what constitutes military vulnerability had prevented the Portuguese from thinking in terms of an international development. As resident representative in Portugal, I was well aware of the strong opposition among water power engineers to transferring first priority from the National Douro to the International Douro.

Engineers as a professional group are over-modest and permit politicians and others to take all the credit for engineering vision and fundamental economic analysis. When a group of outstanding engineers spends two years on a plan, which is finally adopted and recognised as sound and as contributing materially to the national welfare of a country, the credit for that plan should not be lost when admiring the structures recommended in the plan.

GORDON R. WILLIAMS,

Professor of Hydraulic Engineering,
Massachusetts Institute of Technology.

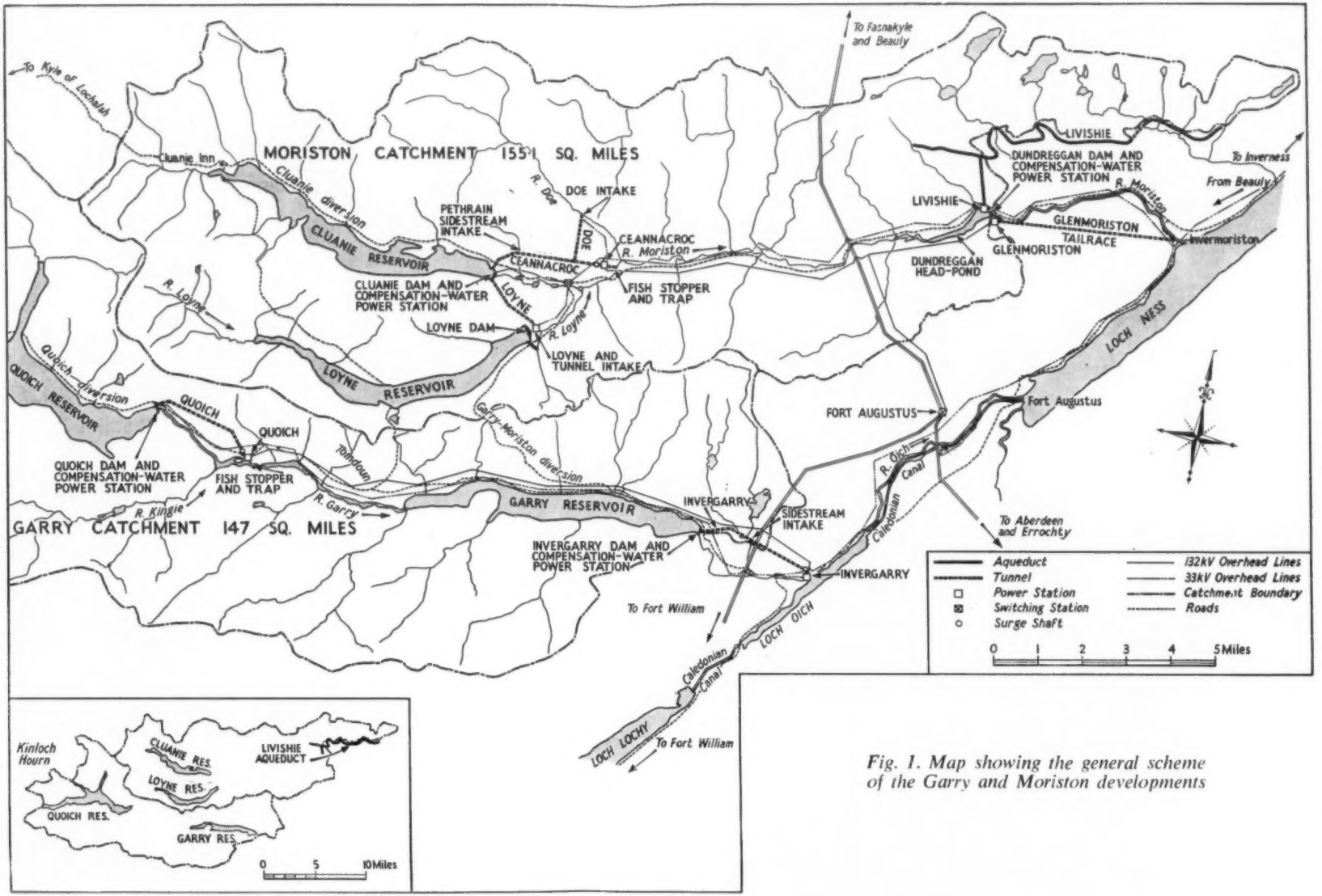

Fig. 1. Map showing the general scheme of the Garry and Moriston developments

Fig. 2. Quoich dam and reservoir

The Garry and Moriston Developments

A description of a co-ordinated hydro-electric scheme, in Glen Garry and Glen Moriston, Inverness-shire, in which some new civil-engineering techniques have been used for the first time in Britain

PART ONE

GLEN GARRY is situated in Inverness-shire, some 40 miles from the town of Inverness and 25 miles from Fort William. The glen is approximately parallel and adjacent to Glen Moriston and although the Garry and Moriston hydro-electric schemes have been promoted separately, construction work in both valleys has been carried out simultaneously and both developments are now being operated as one group with a control centre at Fort Augustus.

Before the North of Scotland Hydro-Electric Board was formed in 1943, there had been several earlier promotions of the combined Glen Garry and Glen Moriston schemes but all of these were rejected by Parliament. In these earlier promotions, it was proposed to develop the Loch Quoich catchment towards the west so as to obtain the maximum head, with a power station on the shore of Loch Hourn at sea level. There had been a great deal of opposition to this proposal and the Board therefore decided to use only the natural catchment area of the River Garry, thus sacrificing about 150 ft. of gross head.

The development consists of a catchment, drained by the rivers Quoich, Kingie and Garry, harnessed to two main power stations, one situated near Tomdoun and the other at Invergarry. A rockfill dam at the eastern end of Loch Quoich forms a large storage reservoir by raising the level of the loch some 100 ft., whence water passes through an 11 ft. 6 in. equivalent diameter horseshoe section concrete-lined tunned 2¾ miles long to the upper power station. This water, together with that from the remainder of the catchment area, passes into a smaller reservoir formed by a small concrete gravity dam, built in the narrow outlet from Loch Garry, which raises the water level by about 20 ft.

A concrete-lined 16 ft. 6 in. equivalent diameter horseshoe section tunnel leads from the dam to the lower power station at Invergarry. Both dams incorporate small compensation sets, and a fish lock is provided at Invergarry.

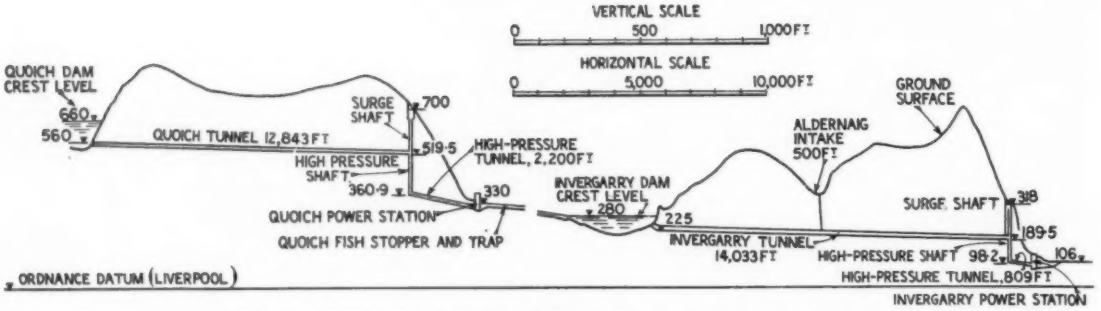

Fig. 3. Longitudinal sectional elevation of the Garry scheme

Quoich Dam

The Quoich dam, forming the main storage reservoir for the scheme, is of rockfill construction with a reinforced-concrete upstream sealing membrane. Before a final design was adopted, several other types were considered and a rockfill proved to be the most satisfactory solution for three main reasons: cement was still in very short supply; tenders submitted were less than for a gravity dam; less shuttering was required and therefore fewer joiners were necessary.

The dam contains 386,000 cu. yd. of rockfill, of which about 100,000 cu. yd. came from the Quoich tunnel and foundation excavations, the balance being supplied from a quarry about ½ mile upstream of the dam. Fill was placed in 2 ft. deep layers, consolidated mechanically and washed down with water to obtain maximum compaction. An upstream membrane was adopted in preference to a central core wall because less rockfill was required and subsequent maintenance work is simplified if the seal shows any sign of deterioration or failure. The membrane is formed in 20 ft. by 20 ft. reinforced-concrete slabs, 15 in. thick at the deepest section of the dam and 12 in. thick for the remainder. The joints between the slabs have been sealed by copper strips, filled with a bituminous rubber compound, which are themselves protected against acid corrosion by the compound. The horizontal joints provide for hinging only, the inclined joints for opening, closing and hinging, and the joint adjacent to the cut-off wall for sliding, closing and hinging.

The top of the dam is cambered in both elevation and plan, in an upstream direction, in order to counteract any settlement that there may be of the finished structure. In each case, the maximum offset is 1 ft. at the deepest section or, in other words, one per cent. of the depth. Hand-packed rubble ranging from a thickness of 7 ft. at the base to 3 ft. at the crest provides a solid support for the upstream slab and absorbs any local settlement.

Certain unusual precautions were taken during construction to reduce natural compaction to a

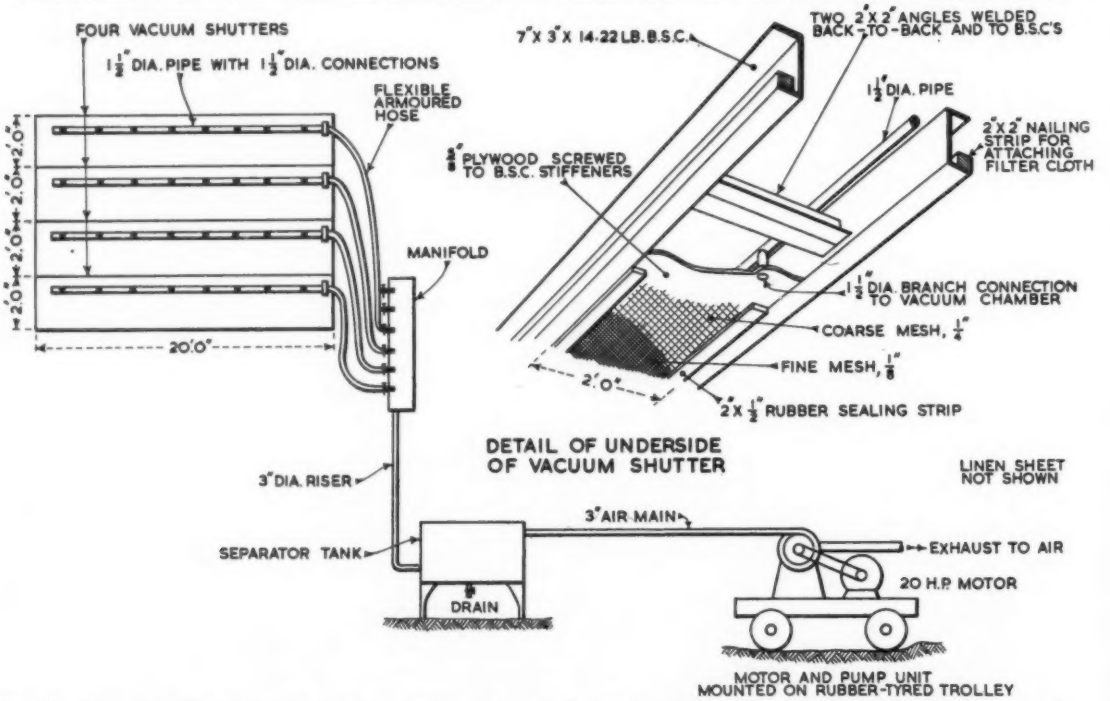
FOUR VACUUM SHUTTERS
1½" DIA. PIPE WITH 1½" DIA. CONNECTIONS
FLEXIBLE ARMOURED HOSE
MANIFOLD
20'0"
7"X 3"X 14·22 LB. B.S.C.
TWO 2"X 2" ANGLES WELDED BACK-TO-BACK AND TO B.S.C'S
1½" DIA. PIPE
2"X 2" NAILING STRIP FOR ATTACHING FILTER CLOTH
⅜" PLYWOOD SCREWED TO B.S.C. STIFFENERS
1½" DIA. BRANCH CONNECTION TO VACUUM CHAMBER
COARSE MESH, ¼"
FINE MESH, ⅛"
2'0"
2"X ½" RUBBER SEALING STRIP
DETAIL OF UNDERSIDE OF VACUUM SHUTTER
LINEN SHEET NOT SHOWN
3" DIA. RISER
3" AIR MAIN
SEPARATOR TANK
DRAIN
EXHAUST TO AIR
20 H.P. MOTOR
MOTOR AND PUMP UNIT MOUNTED ON RUBBER-TYRED TROLLEY

Fig. 4. Arrangement of vacuum equipment for dewatering the concrete panels on the face of Quoich dam

Fig. 5. Upstream face of Quoich dam showing concrete membrane

minimum. Excavated rock containing a high proportion of mica or hornblende was discarded and all material of less than $\frac{3}{8}$ in. was removed from the fill before it was used in order to ensure contact between the pieces. The 2 ft. layers were placed at an upstream gradient of 1 in 24 and, in spreading the rockfill, care was taken to avoid the accumulation of single sized particles in any particular area. The upstream slope of rubble was constructed in 18 in. high steps retained by large blocks of stone and these steps were subsequently incorporated in the hand-packed rubble which was placed after a minimum delay of three months. Most of the fill was put in position at a rate of 17,300 cu. yd. per month and a peak production of 30,000 cu. yd. was obtained on one occasion.

A number of settlement and deflection-measurement stations were established in the dam and readings taken during construction showed a small and fairly uniform compaction as the level of rockfill rose, the maximum recorded being 0·7% of the depth placed. The construction of the upstream membrane was kept well below the level of the rockfill so that the major part of the compaction settlement had occurred before the concrete was placed at any level; since completion of the dam, any settlement has been negligible.

A major problem arose in shuttering the inclined slabs used for the upstream face and this was solved by using a method little known in this country but more common in the U.S.A. This was, in fact, the first time that the vacuum concrete process had been used on a large scale in Britain. Vacuum concrete is material from which, after placing, some of the mixing water is extracted by suction. The principle is that to make a workable concrete that can be placed efficiently in moulds and around reinforcement, it is necessary to use much more water than the quantity required to produce the strongest possible concrete. The shuttering was made up in 3 panels, each 2 ft. deep by 20 ft. wide. After setting side forms and placing reinforcement in position the first of these panels was laid at the bottom of the bay and filled with concrete. The second panel was then placed in position above it and whilst this was being filled with concrete in turn, suction was applied to the first panel. By the time the third panel had been filled it was possible to release the suction on the first and move this into position above the third. The concrete thus exposed was firm and required no further support. This leap frog process was repeated until the whole 20 ft. bay had been concreted. On the average, a suction head of 20 in. mercury was applied for a period of 40 min. The suction is usually effective to a depth of about 6 in. below the pads and the process is therefore particularly suitable for slabs and facing blocks.

A series of tests was carried out at Quoich dam, on an area of fifteen slabs, to determine the most efficient cycle of operation for the vacuum process. This structure thus became a proving ground for principles that may well be supplied to other rockfill dams of a similar nature which may be constructed in Britain in the future. Experience at Quoich showed that the process reduced the water/cement ratio by between 0·05 and 0·07. Further comparative tests were made on two batches of 6 in. cubes, one of which had been subjected to the process, the other being untreated. The former proved to be 20% stronger after 7 days and 4% after 28 days.

Owing to the construction schedule, some slabs had to be concreted during cold weather and, to accomplish this, the aggregates and mixing water were heated; placing was delayed until the air temperature attained 32°F. Despite this precaution, it was found that the vacuum pipes froze and that the process

Fig. 6. Quoich power station seen from across the river during construction

should, if possible, only be used in normal temperatures with short vacuum pipes.

Two culverts have been built at the base of the dam; the first of these has a free-rolling type gate, situated at the upstream end and housed in a tower from which a 120 ft. span footbridge gives access to the crest of the dam. At the downstream end, a 72–60 in. needle valve is installed to control the discharge. A branch from the 6 ft. pipe in the latter culvert feeds the auxiliary turbo-generator. This horizontal Francis turbine was supplied by Gilbert Gilkes & Gordon Limited, and the generator contractor was Bruce Peebles & Co. Ltd. The unit, which has an induction-type generator, has a capacity of 350 kW and operates at 762 r.p.m. under a design head of 113 ft. The turbine discharge provides the compensation water required. The other culvert has been closed by a blank flange and a single-faced sluice which is only used at lower water levels. A side-channel spillway 305 ft. long has been built on the left bank of the reservoir, immediately upstream of the dam, and flood discharge is returned to the river through a concrete-lined channel.

As the maximum water level of the reservoir is above the level of the divide between the catchments of the rivers Garry and Carnach, two very short concrete gravity dams have been built at the lowest point of the divide.

Upstream of the main dam is the intake to Quoich tunnel formed by a deep approach cutting across which is fitted a set of screens, equipped with a cleaning rake. Some distance further downstream, a vertical shaft has been sunk and this houses two gates manufactured by Glenfield & Kennedy Limited. The downstream gate is permanently housed just above the soffit of the tunnel and is normally used for complete tunnel closure, whereas the upstream unit is held in the gate house at the top of the shaft and is lowered only when the downstream gate is out of service for maintenance or repair.

Between the intake and the surge shaft, the tunnel is horseshoe in cross section; of 11 ft. 6 in. equivalent

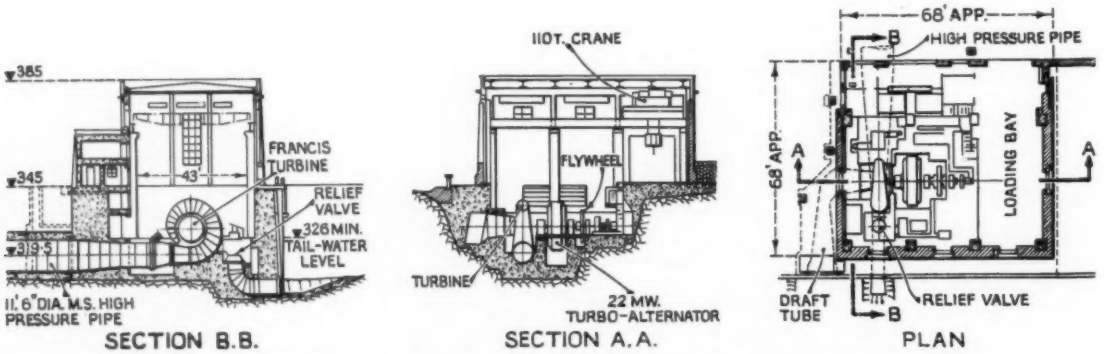

Fig. 7. Sectional elevations and plan of Quoich power station

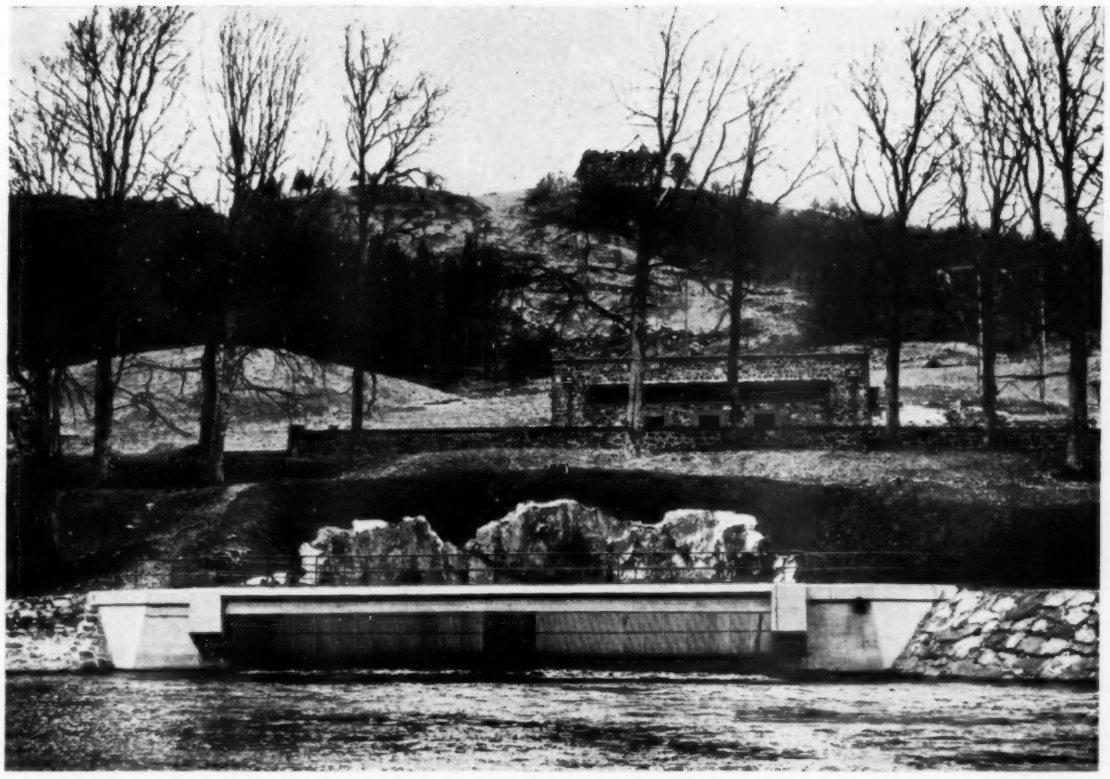

Fig. 8. Invergarry power station seen from Loch Oich. The road from Fort William to Inverness passes in front of the station

diameter, 12,843 ft. long and concrete lined throughout. The surge shaft, of the orifice type, is 169 ft. deep, the top 40 ft. being 45 ft. in diameter and the remaining section, 30 ft. in diameter. At the bottom of this surge chamber, a 158 ft. deep and 11 ft. 6 in. diameter shaft has been driven to carry the water into the high-pressure tunnel, which is 1,440 ft.+820 ft. of pipe.

Quoich Power Station

The power station at Quoich is the only station in the two glens to have been built entirely on the surface. As in all hydro-electric schemes in Scotland, the building itself has been carefully designed to blend with the countryside and the result is very satisfactory from an aesthetic point of view.

The power station is equipped with one 22 MW horizontal-shaft Francis turbine, manufactured by Boving & Co. Ltd., and operating at 300 r.p.m. under an average gross head of 312 ft. and a design head of 255 ft. The annual load factor is 40% and the discharge at rated capacity and mean head is 1,034 cusecs. The alternator, with a capacity of 23,155 kVA, was supplied by the English Electric Co. Ltd., the main transformer capacity being 25,000 kVA.

The turbine is designed for a maximum output of 30,300 b.h.p., or 28,000 b.h.p. at the design head, and the maximum runaway speed is 580 r.p.m. The runner is constructed of a special nickel-aluminium bronze known as nikalium and was designed specifically for the particular operating conditions at Quoich. It is provided with replaceable sealing rings at the peripheral surfaces opposite to the stationary sections and is secured to the shaft by special studs and a key.

The alternator is rated at 22,000 kW, 0·95 p.f., 11 kV, and operates at 300 r.p.m. It is ventilated on the open-circuit system and has three main bearings on which are mounted the rotor and flywheel. The bearing at the turbine end includes two thrust bearings which take the two-way axial load from the turbine. Both the main and pilot exciters and the governor alternator are directly coupled to the alternator shaft.

All centre and exciter end bearings are of the Michell type, in which the shaft journal is carried on the babbitted surfaces of two pads which rest on the inner periphery of a semicircular cage mounted in the pedestal. A short axial line pivot on the back of each pad allows it to tilt circumferentially so that an oil wedge is formed between its surface and the shaft when the latter is rotating.

The inner periphery of the pedestal cap is also lined with whitemetal and the cap itself is so shaped that it forms a reservoir. Normally this reservoir is kept filled, partially by oil which is carried round by the shaft and forced up a central chimney over which it spills into the reservoir, and partially by oil bypassed from the main feed pipe. An overflow pipe drains any excess oil from the reservoir to the well in the pedestal. Oil throwers and wipers are provided at each end of the bearing to prevent oil leakage along the shaft.

Although Quoich power station is at present controlled from a pushbutton panel in the turbine chamber, provision has been made for future conversion to full remote control when required.

Invergarry Dam and Reservoir

Loch Garry drains a catchment area of 147 sq. miles over which there is an estimated average annual rainfall of 101 in. The storage capacity is 825 m.c.f. with a maximum flood level of 290 ft. O.D. and a spillway crest level at Invergarry dam of 280 ft. O.D.

Apart from being the smallest main dam in the combined Moriston and Garry developments, the structure at Invergarry is also the most curious in design, because the only site available was in a very narrow gorge at the juncture of the loch and the river Garry. The dam contains 6,300 cu. yd. of concrete and is provided with two lifting flood gates, two compensation-water turbines and a Borland fish pass; it has raised the water level by about 20 ft. and the maximum flood rise is 33 ft. A 24 ft. equivalent-diameter concrete-lined diversion tunnel, 618 ft. long, was driven to discharge the floods from the side channel spillway. This was provided with a 174 ft. long free spill crest and situated on the north side of the dam. During construction of the dam the tunnel was used to divert the river Garry.

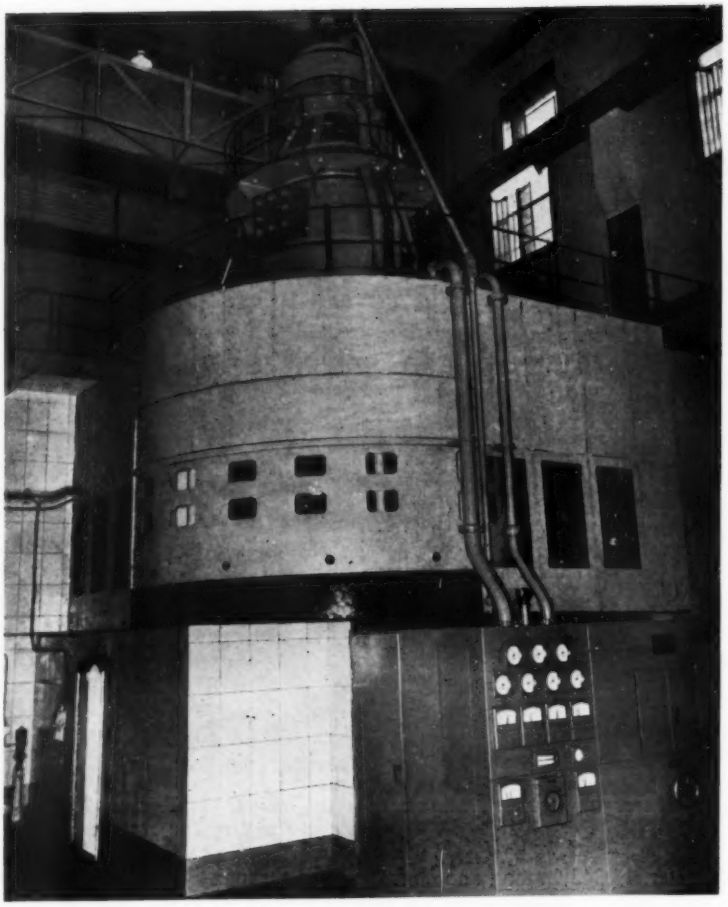

Fig. 9. The 20 MW English Electric Kaplan set in Invergarry power station

Two auxiliary turbines are provided to cater for summer and winter compensation water flows. One unit has a capacity of 285 kW at a turbine speed of 230 r.p.m. and a generator speed of 760 r.p.m., the other 30 kW at 762 r.p.m., the design head being 27 ft. in each case. Both turbines were manufactured by The Armfield Hydraulic Engineering Co. Ltd. and the induction generators were supplied by Bruce Peebles & Co. Ltd.

The intake to the Invergarry tunnel is fitted with a complex system of screens having apertures small enough to prevent smolts being drawn into the tunnel. These screens require constant attention at certain times of the year and a rail-mounted gantry has been installed to simplify and accelerate lifting and cleaning operations. A great deal of thought has been given to the problem of trash at this dam and although there have been some setbacks, it is probable that some efficient system will eventually be evolved requiring less manpower and inspection.

Work on the conduit between the tunnel intake and Invergarry power station was undertaken in five sections, each having an equivalent diameter of 16 ft. 6 in. The low-pressure stage is 14,033 ft. long, horseshoe shape in section and concrete lined throughout, the high-pressure shaft being 91 ft. deep and circular in section, as also is the 800 ft. long length of tunnel between the shaft and the steel pipes leading into the station. The differential surge shaft is 107 ft. deep, with a 14 ft. 6 in. internal diameter riser inside a 95 ft. diameter shaft.

Even before Invergarry dam was built, passage through the gorge had always been difficult for fish, and it was found necessary to improve the access to the fish lock. Rocks on the south side of the gorge are unstable and, if interfered with, might block the channel on some future occasion, and so a small tunnel was driven through sound rock on the north bank, with six pools raising the water level in 12 in. steps.

Invergarry Power Station

Work on the lower Garry development began in 1951 and the power station was first commissioned early in 1956. The station is semi-underground; an original scheme differed from the one finally adopted in several respects, because it was decided that the conditions would be better satisfied by a single unit rather than by the two originally envisaged. The station is unusual in that a vertical Kaplan of 28,000 b.h.p. capacity operating at 250 r.p.m. has been used in conjunction with the relatively high average gross

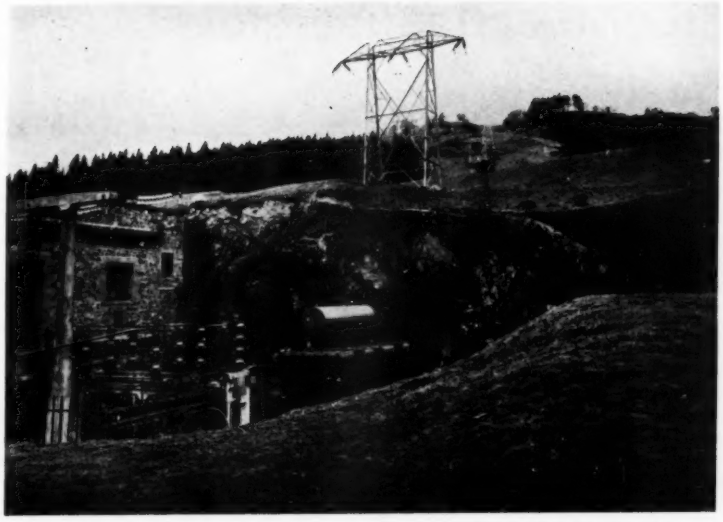

Fig. 10. Invergarry transformer compound showing 25 MVA transformer and 125 kV line entry

head, for this type of turbine, of 169 ft. and a design head of 146·4 ft. Both the turbine and the alternator were manufactured by the English Electric Co. Ltd.

The low-level power station is situated on the north side of the Inverness-Fort William road, and the draught tube passes under the highway and discharges back into the river Garry through screens provided to prevent salmon entering the tailrace. The machine chamber is 60 ft. high from the turbine floor to the roof, 80 ft. long and 52 ft. wide. The transformer compound is adjacent to the main road, alongside the station which has been built in poor quality rock requiring a concrete facing. A cavity has been left between the facing and the brick panel walls to allow the collection of any seepage water. All parts of the building above ground have been very attractively faced with masonry. As a result of the relative elevations of the access road, inlet tunnel, turbine setting and tailrace, a somewhat unusual internal design has been used in that the assembly bay is above the turbine inlet butterfly valve and extends to the alternator centre line.

Interior lighting at Invergarry power station is provided by a system of fluorescent tubes fitted below the crane runway. The alternator is designed for open-circuit ventilation and it has therefore been necessary to install motor-operated air-inlet louvres in the station wall in front of viscous filters, and manually adjusted high-level hot-air outlet louvres. Filtered air drawn from the outside passes through the alternator and is then discharged into the station through apertures in the stator frame. Damper doors in the entrance of the air inlet duct are electrically operated to open when the unit is started and to close when it is shut down or if a fire occurs in the alternator. A thermometer and thermocouple are provided in the air inlet and outlet and both instruments are fitted with alarm contacts which close when the temperature rises to 45°C. and 65°C. respectively.

(To be continued)

East Kilbride Laboratory Changes Its Name

The Council for Scientific and Industrial Research announces that in future the Mechanical Engineering Research Laboratory at East Kilbride, near Glasgow, will be known as the National Engineering Laboratory. This is because the Council considers it desirable to emphasise the national character of the Laboratory, which is part of the D.S.I.R. organisation and is financed from public funds. It does not imply any change in the field covered by the Laboratory, which will continue to be concerned with problems of mechanical engineering.

The Council has also decided to set up a Steering Committee to look after the programme of the Laboratory. As a result of a recent review of the functions and activities of the Laboratory, the Council is convinced that between the proper and reasonable activities of the universities and technical colleges on the one hand and research associations and private and nationalised industry on the other, there is an important place for a national establishment for research in mechanical engineering, mainly supported by public funds. The new Steering Committee will be under the chairmanship of Vice-Admiral Sir Frank Mason, K.C.B., M.I.Mech.E., M.I.Mar.E., who is a member of the Research Council and chairman of the outgoing Mechanical Engineering Research Board. The members of the Committee will be Professor O. A. Saunders, M.A., D.Sc., M.I.Mech.E., F.Inst.P., F.Inst.F., F.R.S.; Norman Elce, Esq., M.Sc.Tech., M.I.Mech.E.; Dr. D. G. Sopwith, C.B.E., D.Sc., M.I.Mech.E., Director of the Mechanical Engineering Research Laboratory; and Dr. C. M. Cawley, C.B.E., D.Sc., F.R.I.C. In order to assist the Director as the Laboratory expands and to improve and extend the links between the Laboratory and industry, two Deputy Directors have been appointed. They are Dr. S. P. Hutton and Mr. F. D. Penny. Dr. Hutton, who has been Head of the Fluid Mechanics Division, will have special responsibilities for fostering closer relationships with industry, Mr. Penny for the management of the research programme.

Tape Spooler. Ferranti Limited have developed a tape spooler for handling paper tape of any of the three standard widths—$\frac{11}{16}$ in., $\frac{7}{8}$ in. and 1 in. It is intended primarily for use with Ferranti high-speed tape readers. A pamphlet, "Ferranti Tape Spooler A11," gives full particulars.

Measurement of Liquid Flow by Ultrasonics

A detailed description of the principles involved in measuring flow by ultrasonics with particular reference to the potential of the ultrasonic flowmeter for measuring turbine efficiency

By R. E. FISCHBACHER, B.Sc., A.R.C.S.T., A.M.I.E.E.

THE problem of measuring the flow rate of liquids, whether in closed pipes or in open conduits, has long occupied the attention of engineers. Despite the considerable effort which has been devoted to the subject throughout the years the ideal flowmeter has not emerged. Nor is it likely to emerge. The requirements of different applications are so diverse that it is unlikely that they can ever be reconciled in a single instrument.

Where the flow to be measured is in enclosed pipes, there is a need for a reliable flowmeter which will measure the flow of any liquid while being independent of its characteristics and providing no obstruction in the pipe to impede free flow. Where the flow is in open conduits, obstruction to flow may be of less importance provided the obstruction is not great, but reliability and robustness with little or no attention are important.

In both cases the effect of velocity profile is important, and ideally the indication should be independent of this factor.

In recent years the science of ultrasonics has been applied to the measurement of flow, and a number of schemes have been successfully developed, chiefly in U.S.A., both for measurement in pipelines and in open conduits or estuaries.

Principles

Essentially all schemes compare the velocity of flow with the velocity of propagation of sound in the fluid. Since this velocity is not constant, but is dependent upon temperature and pressure as well as upon the constituents of the fluid, the indication of the instrument may also be affected by these variations unless precautions are taken to prevent it.

If two ultrasonic transducers are placed in a fluid as in Fig. 1, then the time taken for a pulse of sound emitted from one to reach the other is

$$t_0 = \frac{d}{c}$$

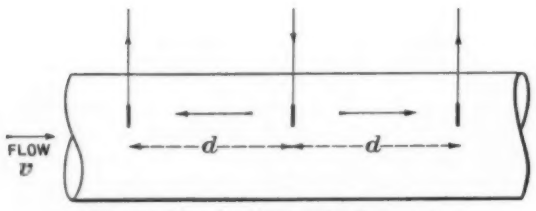

Fig. 1. Simple ultrasonic flowmeter

where d is the distance apart, and c is the velocity of propagation of sound in the fluid. Should the fluid be flowing in the direction of propagation with velocity v, the time of transit will be reduced to

$$t_1 = \frac{d}{c+v}$$

Since c is in the region of 1,500 m. per sec. and is normally very much greater than v, t_1 will not differ greatly from t_0. Furthermore, owing to the variations of c which may be caused by temperature and pressure, t_0 is not a stable quantity. Any attempt to derive v from these two transit times is not therefore likely to prove accurate.

Note, in passing, that the transducers will not in practice protrude into the flow, but will be set into the pipe or conduit wall. Fig. 2 illustrates one practical method.

A more satisfactory variant is provided if a second transducer is placed upstream of the transmitting transducer, also spaced by d from it. The time taken by the sound pulse in travelling to the upstream transducer is

$$t_2 = \frac{d}{c-v}$$

If the difference between the times of arrival of the upstream and downstream signals is measured, we have

$$\Delta t = t_2 - t_1 \doteq \frac{2dv}{c^2}$$

where v is very small compared with c.

This is a practical system, provided due account is taken of the c^2 term in the denominator. An extension of this system to the use of continuous waves rather than pulses can be made if the phases of the signals arriving at the two receivers are compared. The phase difference $\Delta\phi = \frac{2\omega dv}{c^2}$ where $\omega = 2\pi f$ is the angular frequency of the signal.

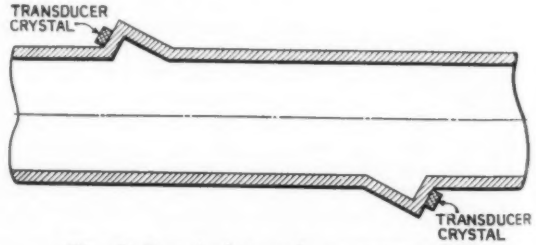

Fig. 2. Practical transducer arrangement

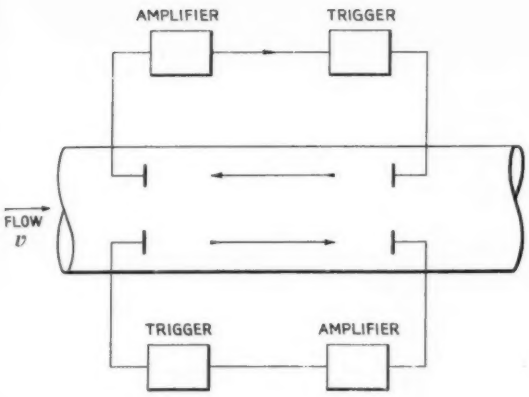

Fig. 3. Oscillating loop system

To eliminate the effect of c in the above expressions, an alternative system has been developed. This is illustrated in Fig. 3.

Consider a pair of transducers as before. A pulse is emitted from the transmitter to a receiver downstream. The pulse is received after time t_1, is amplified, and virtually instantaneously fed back to the transmitting transducer for retransmission. A pulse is therefore emitted every t_1 seconds; that is, a train of pulses is emitted of frequency

$$f_1=\frac{1}{t_1}=\frac{c+v}{d}$$

Another train of pulses is generated by another transducer pair operating in an upstream direction at a frequency

$$f_2=\frac{1}{t_2}=\frac{c-v}{d}$$

It is a simple matter to extract the difference or beat frequency

$$\Delta f=f_1-f_2=\frac{2v}{d}$$

which is seen to be independent of c. We shall refer to this system as the oscillating loop system.

A third system which has been employed depends upon the deflection of a narrow beam of ultrasonic waves by the flow. The well-defined beam is directed from a suitable transmitting transducer across the flow to a differential transducer in the opposite wall of the pipe or conduit (see Fig. 4). When there is no flow, the beam is received equally by the two halves of the differential receiver. When flow occurs the beam is slightly deflected downstream by a distance

$$x=\frac{dv}{c}$$

and the signals received by the two halves of the receiver are no longer equal. The signal incident on the downstream half increases while that on the upstream half decreases.

Where the pipe diameter d is small, appreciable deflection of the beam can only be obtained at very high flow rates. It might appear that if the pipe diameter or conduit width were large enough, adequate deflection could be obtained at low flow rates, but it must be remembered that the beam produced by the transmitter is not exactly parallel, but will diverge slightly, and that its passage along a considerable path length in the medium may impair beam definition. This will in turn adversely affect the operation of the differential receiver.

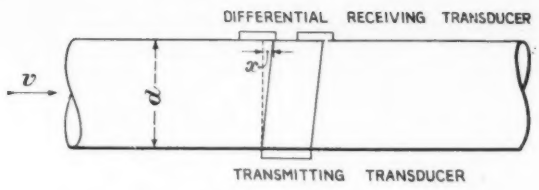

Fig. 4. Beam-deflection system

Limitations

The principles outlined above indicate the basic mechanism of several versions of the ultrasonic flowmeter. There are, of course, the usual practical difficulties to be encountered in realising the results predicted by the simple theory. In the case of the beam deflection system one of the limitations has already been outlined—namely that of the flow rates to which it is applicable.

Consideration of the values obtained for the beat frequency in the oscillating loop system also shows that if very low beat frequencies, such as fractions of a cycle per second, or a few cycles per second, are to be avoided, either the flow rate has to be very high or the pipe diameter must be small. Taken alone, this may not constitute an overwhelming difficulty, but there are other problems to be discussed later.

The phase-difference system above permits scaling to different flow rates and pipe dimensions. The phase difference $\frac{2\omega dv}{c^2}$ contains a frequency term ω as an additional variable. For accurate measurement of phase the full-scale phase difference should be as close to 2π as possible. For any given pipe size and maximum flow velocity, the frequency employed can be varied to give the required phase difference. In this respect the phase difference scheme is more adaptable to low flow rates.

The two main contenders for low flow-rate measurement are the oscillating loop and phase-difference systems. In the form in which they have been considered there is one severe practical problem. In the derivations of the expressions on which they depend it has been assumed that the value of c, the velocity of sound propagation is invariant. Suppose that c is not the same in the two paths and that the velocity in one path is c while in the other path it is $c+\Delta c$.

The transit times are now

$$t_1=\frac{d}{c+\Delta c+v}$$

$$t_2=\frac{d}{c-v}$$

In the case of the time or phase difference systems, the time difference becomes

$$\Delta t=t_2-t_1=\frac{2d}{c}\left(\frac{v}{c}+\tfrac{1}{2}\frac{\Delta c}{c}\right)$$

and the phase difference

$$\Delta\phi=\frac{2\omega d}{c}\left(\frac{v}{c}+\tfrac{1}{2}\frac{\Delta c}{c}\right)$$

Since v/c is a very small quantity in the low flow condition, $\Delta c/c$ need not be large to contribute a considerable error.

The implication of this is that unless propagation

conditions in the two paths are identical, appreciable errors may occur. If v/c is 10^{-3}, $\Delta c/c$ need only be of the order of 10^{-4} to cause 5% error.

To ensure that path conditions do not differ appreciably, it has in some cases been arranged that the two paths are side by side in the pipe. The transmitter for one path and the receiver for the other are located together in one wall of the pipe and their counterparts in the opposite wall. While this arrangement ensures that the two paths are close to each other, there are disadvantages when the ultrasonic attenuation is small, as in water, because reflections from the opposing transducers may cause energy from a transmitting transducer to fall on the receiving transducer alongside it, despite any measures to prevent direct coupling of energy between the two. This constitutes coupling between the two independent parts of the system and will cause errors.

It would be logical to use only one path, thus eliminating any differences due to two separate paths. Schemes to do this have in fact been used. The simplest of these consists of making a measurement of time or phase difference between a single pair of transducers with the signal passing first in one direction, and then reversing the direction of signal and making a measurement of time or phase difference in this reverse direction. The difference between the stored first reading and the second gives an indication of the flow velocity. In this case the measurement is made over the same path, but at slightly different times. An alternative possibility is to emit pulses of energy simultaneously from the two transducers, and while the pulses are in transit through the fluid to change the role of the transducers from transmitters to receivers. The two pulses will then be received at slightly different times since one is going upstream and one downstream, the time difference being a measure of flow velocity. In this case the pulses have traversed different parts of the flow path at different times, but since propagation velocity is very high they can be regarded as being virtually simultaneous in time and common in path.

Corrections

It will be noted that in two of the systems described the indication of the system is affected by the velocity of sound c. It has also been pointed out that the velocity of sound in a liquid is not constant, but is dependent upon temperature, pressure and constituents of the fluid.

If the readings of these systems are to be independent of sound velocity then correction must be made to take account of changes in this parameter. If c can be measured directly, correction can be made by simple analogue computational methods.

The method made use of in the beam deflection system depends upon the fact that the acoustic impedance of a radiating surface is proportional to ρc, the product of the density and the velocity of sound in the fluid into which it radiates. This impedance is allowed to control the amount of energy radiated by the transducer, and the strength of the received signal is then proportional to ρc as well as to the beam deflection. The output of the system is therefore

$$F = k\,\frac{dv}{c}\cdot\rho c$$
$$= kd\rho v$$

where k is a constant of the system.

It will be noted that this is proportional to mass flow ρv, and is independent of c.

In the case of phase and time difference systems, the transit time in one direction is

$$t = \frac{d}{c \pm v}$$

Where the flow rate is slow, i.e. v is very small compared with c

$$t \doteqdot \frac{d}{c}$$

Since d is fixed, c can be derived from this expression and used for correction. Where greater accuracy is required, the sum of the upstream and downstream propagation times

$$t_1 + t_2 = \frac{d}{c+v} + \frac{d}{c-v} = \frac{2dc}{c^2 - v^2} \doteqdot \frac{2d}{c}$$

can be used.

An alternative possibility is an arrangement whereby d varies directly as c^2; d/c^2 then becomes a constant term. This is a feasible solution.

Effect of Velocity Profile

Since the velocity of flow will not be uniform across the section of the pipe or conduit, some consideration has to be given to the effect of this on the meter.

The ultrasonic beam takes a substantially linear path across the pipe, and the beam deflection or time delay is integrated linearly across the pipe. On the other hand, the volume of fluid flowing at any given velocity is dependent upon the cross-sectional area of the annulus of fluid flowing at that velocity; that is, it is a two dimensional effect. Therefore, although the ultrasonic flowmeter reading takes some account of velocity profile it does not correct completely for it. Some calibration will therefore be necessary. Work carried out by Kritz[1] suggests that after initial calibration good accuracy can be maintained over a wide range of Reynolds' number.

Applications in the Hydraulics Field

A variant of the phase difference system has been employed by Swengel, Hess and Waldorf[2] for the measurement of flow in hydro-electric turbine testing. The conduit in which measurements were made was 25 ft. deep and 16 ft. wide. In order to average results over the profile, a new transducer was developed, consisting of a $\frac{1}{4}$ in. diameter stainless steel rod which traversed the conduit at an angle, and was arranged to radiate ultrasonic energy down the pipe across the whole profile. A second rod downstream acted as

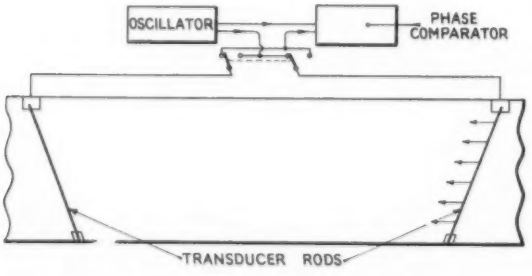

Fig. 5. Swengel, Hess and Waldorf's system

receiver, and the roles of the two transducers were periodically reversed (see Fig. 5). The phase differences in the two directions were measured and used to derive the flow rate. Accuracy better than 1% was claimed in laboratory tests on small scale models with straight flow sections.

Knapp[3] describes an oscillating loop system applied to water flow in large conduits. Here the transducers were mounted in opposite walls of the 10 m. wide conduit. The results obtained agreed to within 0·8% with those obtained with propeller-type flowmeters.

In a series of tests on a laboratory model where disturbed and asymmetric flow conditions could be simulated, errors recorded were of the order of 1%, except where the equipment was being used toward the bottom of its range, where the errors increased slightly.

Future Possibilities

The ultrasonic flowmeter is as yet in its infancy and has only emerged in a practical form in the last few years. Its applications and problems are beginning to be understood more clearly and with that understanding a clearer idea of its potentialities will appear. Development is continuing in the United States of America, in Europe and in this country, both in the fields of hydraulics and that of process industry flow measurement.

In the hydraulics field, the work of Knapp shows that useful accuracy can be obtained with a particular system, which is, no doubt, capable of further development. Development at present under way in this country appears likely to yield, in the near future, a simple submersible probe-type ultrasonic flowmeter which may be used as a portable instrument, or whose probes may be permanently installed in the flow in the manner of the pitot tube, without danger of altering calibration or clogging up. A similar portable device whose transducers may be clamped on the outside of a pipe to indicate internal flow velocity also appears to be a possibility.

It seems, therefore, that the ultrasonic flowmeter may in the future make its presence felt more widely, both in the hydraulics world and in the process industry.

Acknowledgment

This article is published by kind permission of the Council of the British Scientific Instrument Research Association.

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Volta River Reassessment Report

Under an agreement between President Eisenhower and Mr. Nkrumah, Prime Minister of Ghana, the Henry J. Kaiser Company sent a technical team to Ghana last autumn, and a Reassessment Report was submitted to the Government of Ghana by the Henry J. Kaiser Company at the end of February 1959. Basically, this report recommends that the main dam site should be moved to Kosombo (about a mile south from the original site at Ajena), and proposes that a generating plant with an installed capacity of 768 MW should be built there at an estimated cost of £55,700,000 (January 1959 prices). It is considered that the Kosombo dam and power plant could be constructed to deliver initial power in 5½ years after the decision to proceed with the project. This includes 1½ years for engineering and 4 years for construction. The proposed initial installation would comprise four generators of 128 MW capacity each, with two to be installed later as required. An additional low-head dam and power plant is considered feasible at Kpong Rapids with installed capacity of 140 MW. Utilising the controlled flow from the main dam, this development would add a continuous power supply of 113 MW to the system. This plant would be constructed after all installations at Kosombo, at an estimated cost of £15,500,000 based on January 1959 prices.

The dam and power development at Bui is considered to be feasible and economic. It would be built as a future addition after the installations at Kosombo and Kpong to provide 93 MW of average power capacity to the national system as required. It is estimated that the cost of this installation, including the transmission link to Kumasi, could be constructed for £25,500,000 (January 1959 prices).

The report estimates that the cost of a general power supply delivered from the Ghana transmission network would range from an initial 0·609d. per kWh to 0·524d. per kWh under full development. This contrasts with present 1·99d. per kWh fuel and operating cost of diesel generating plants. Estimated cost of power to the aluminium industry would range from an initial cost of 0·222d. per kWh to 0·173d. per kWh under full development. Basically, this means that the reassessment of the engineering aspects of the project indicates that more power could be generated from the Volta than was anticipated originally, and at a lower cost.

In view of the favourable nature of the Kaiser Report and in keeping with the Prime Minister's original approach to President Eisenhower, the Government of Ghana has requested the Government of the United States to continue its efforts to interest aluminium companies in using power from the Volta, and in addition to seek to interest other possible large-scale users of such electricity. It is appreciated that this is a large and difficult task, and a number of months will be required before any results can be expected.

In the meantime, the Government of Ghana has decided that certain preliminary works at the dam site should be undertaken without delay. Briefly, the scope of this work will cover foundation exploration, determination of site conditions, determination of basic design of dam and power plant, the construction of access roads, the construction of some housing at the dam site, and construction mobilisation planning. The Government has now signed an agreement with Kaiser Industries to carry out this work.

Fig. 1. Outline of the main storage reservoir on the Malta

Plans for the Drau Basin

An outline is given of future projects contemplated by Österreichische Draukraftwerke A.G. (ÖDK)

By Dr. E. KÖNIGSHOFER

THE second Nationalisation Law of 1947, on which the public electricity supply in Austria is based, made provision for the establishment of the ÖDK with a view to developing the south-eastern part of the country. In regard to the largest river in the area, the Drau, extensive planning and constructional work had already been undertaken in the time of the Third Reich. As a result of the peace treaty concluded after the Second World War the frontier was changed in such a way that only two sites on the Drau stages remained in Austria—the Schwabeck and the Lavamünd, while the Unterdrauburg and Marburg a.D. which were under construction at the end of the war, fell to Yugoslavia.

The Schwabeck plant was built in accordance with the plans of Professor Grzywienski and completed in 1943, comprised three generating units and had an overall capacity of 60 MW and a power production of 350 million kWh per annum. Until the completion of the Glockner-Kaprun Tauern plant it was used for maintaining frequency in the entire Austrian interconnected network.

The second Austrian plant, Lavamünd, was put into operation with two generating units in 1945; the third generator was installed and put in operation in 1949 by the ÖDK. The generating capacity of this plant amounts to 24 MW, yielding a power production of 138 million kWh in a normal year. It is of interest to note that this plant was designed as a pier plant, that is, the customary power house was dispensed with and the generating units are distributed within the various piers. This method of constructing a hydroelectric plant stems from Dr. Grengg, professor at the Institute of Technology, Graz.

The power plants which Austria possessed after the termination of the war were predominantly run-of-river plants. In order to be in a position to provide peak energy, the ÖDK was entrusted with constructing the Reisseck-Kreuzeck group of power plants which is now nearing completion. This scheme, which will have a capacity of 132 MW, yielding an annual production of 348 million kWh, has already been described in this journal (February 1954).

After its establishment the ÖDK took over the Voitsberg thermal plant, which at that time was equipped with two generating units of 20 MW each and enlarged it by adding a third unit. In addition, a second thermal plant was built having a capacity of 65 MW, which at present is the largest unit that Austria possesses; the live steam temperature is 986°F.; it has double reheating and is designed for a pressure of 1,572 lb. per sq. in. at the turbine intake.

To utilise the lignite deposits in Carinthia, which are estimated at 70 million tons, the ÖDK was charged in 1949 to erect a thermal power plant at St. Andrä having a capacity of 67·5 MW. This plant is now being enlarged by the addition of a steam driven generator of 110 MW capacity.

Thus the ÖDK is approaching the completion of the tasks originally entrusted to it and is now projecting further developments. These include the construction of run-of-river plants along the Drau not yet utilised, and the construction of a peak power plant for which plans have already been worked out.

Furthermore, the erection of an additional thermal power plant located on a mine site at Fohnsdorf, Styria, is envisaged.

Fig. 1 shows the area in which the ÖDK.WAG plants are situated.

Projects for a Chain of Plants along the Drau

Due to the climatic conditions prevailing on the southern slopes of the main range of the Alps the Drau river has a considerable flow even during the winter months, as thawing sets in there much earlier than in the northern parts of Austria. Under the outline plan for the utilisation of the Drau for power production the following stages are envisaged:

The Edling stage, which is nearest to the existing Schwabeck plant is the first to be scheduled for execution. On the basis of hydrological investigations an average annual water flow of 9,600 cusecs has been established for the catchment area of 4,100 sq. miles per annum. The turbines will be designed for a utilisable flow of 14,200 cusecs. With a net head of 59·5 ft., an annual production of 360 million kWh may be expected. For the chain of plants on the Drau a continuous storage operation is planned. At Feistritz in the Rosental a storage area of about 1·35 sq. miles can be formed.

Inner Malta Valley - Kolbnitz Project

Figs. 1 and 4 show the site where the plant is to be erected, as well as the interconnecting watercourses. Near Spittal a.d.D. the Lieser joins the Drau; a tributary of the Lieser is the Malta. Fig. 4 shows that several rivulets, among them the Göss, discharge into the Malta. The upper Malta valley offers very favourable hydraulic conditions. At an altitude of 4,920 ft. the annual precipitation amounts to about 54 in. per annum, and at 9,840 ft. about 91 in. per annum. In the higher altitudes 40% to 90% of this precipitation falls in the form of snow. Also the geological and topographical conditions are very favourable for the creation of a storage reservoir. For these reasons the region in question has aroused great interest among power economists who have long been convinced that the Malta valley is a very suitable site for the construction of a large reservoir which, when the water is utilised at Kolbnitz in the Möll valley, will command a high head. The project elaborated by the ÖDK in recent years makes provision not only for the utilisation of the Malta but also of its southern tributaries, among which are the Göss rivulets.

Fig. 4 shows the projected plant to consist of the following components:—

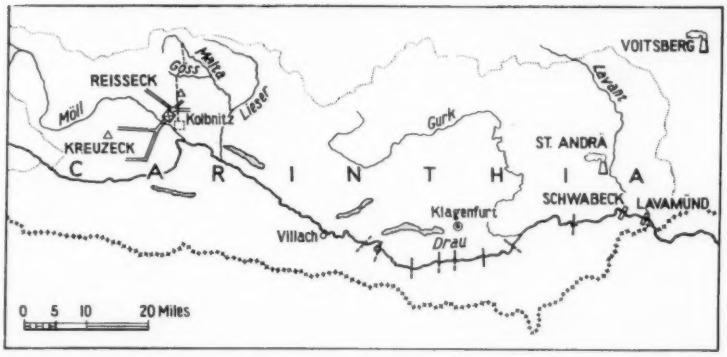


Fig. 2. Map of the Drau basin showing sites of the proposed developments

Fig. 3. Outline of auxiliary reservoir with main dam in the background

TABLE I.—PROPOSED PLANTS ON THE DRAU

Plant	Installed capacity	Annual production
	MW	million kWh
Edling	70	360
Annabrücke	49	260
Dullach	26	135
Ferlach	26	135
Hollenburg	26	135
Feistritz/Rosental	57	280
Rosegg	25	125
St. Martin	35	170
	314	1.600

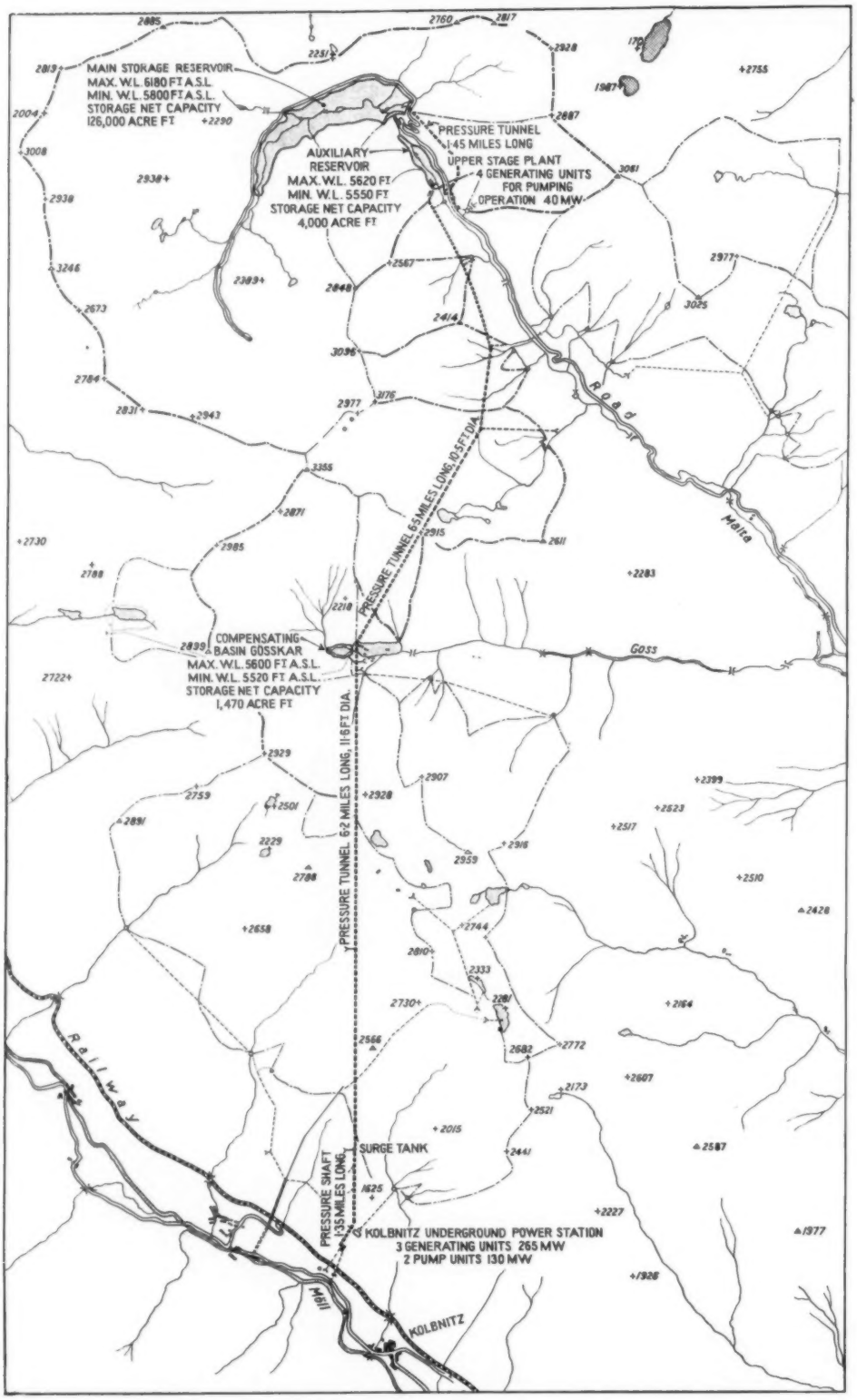


Fig. 4. Map of the Inner Malta Valley-Kolbnitz project

1. A main storage reservoir with a net storage capacity of 126,000 acre-ft. equivalent to an energy value of 417 million kWh. The natural catchment area was ascertained to amount to 19·5 sq. miles and the area to be submerged to be 530 acres. The maximum water level has been fixed at 6,187 ft. above sea level and the minimum water level to be 5,800 ft. In designing the dam, shown in Fig. 1 (left) and the background of Fig. 3 the principle of the multiple equiangular wall was followed, the characteristic feature of which is that the radius decreases towards the bottom while the angular width is maintained equal as far as possible on all levels. The crest of the dam, at an elevation of 6,190 ft. will have a length of 1,780 ft. and the maximum height of the dam will be 590 ft.

2. A headwater tunnel 1·45 miles long with a diameter of 10·6 ft. which conveys the water to the Upper-Stage plant.

3. The Upper-Stage plant is located at the foot of the auxiliary reservoir mentioned under (4) and has a mean capacity of 30 MW and a maximum capacity of 40 MW. The rated utilisable flow will be 1,060 cusecs the mean gross head 410 ft. and the mean net head 375 ft., the mean energy factor being 0·008 kWh per cu. ft. Here not only is the water of the main storage reservoir utilised by the auxiliary reservoir mentioned under (4), but water is also pumped into the main reservoir.

In the Upper-Stage plant four vertical generating units each of 10 MW (12·5 MVA, 10 kV) with pump-turbines will be installed. A transformer of 50 MVA steps up from 10 to 110 kV.

Pumping in the Upper Stage is designed for a mean delivery of 800 cusecs for a mean static lift of 470 ft. and a mean pumping capacity of 40 MW. The mean energy factor is 0·014 kWh per cu. ft.

4. The auxiliary reservoir has a storage capacity of 4,000 acre-ft. Its energy value amounts to 12 million kWh; its maximum water level has been fixed at 5,620 ft. and its minimum level at 5,550 ft. The natural catchment area extends over 2·7 sq. miles, or, including the river diversions, over 11 sq. miles. The area to be submerged amounts to 75 acres.

As Fig. 4 shows, the reservoir is created by the construction of an arch dam and of a small auxiliary dam. The dam will be designed as a gravity arch dam with a crest length of 575 ft. and a maximum height of 180 ft., the crest level being at an elevation of 5,620 ft. The auxiliary dam, which has a similar crest level, has been designed as a gravity dam with a crest length of 230 ft. and a maximum height of 650 ft.

5. The pressure tunnel 6·5 miles in length has an inside diameter of 10·5 ft. and leads to the Gösskar compensating basin (cf. item 6). Into this pressure tunnel several rivulets are also diverted.

6. The Gösskar compensating basin has a natural catchment area of 3·9 sq. miles, or if the various water diversions are included, extends over 7·15 sq. miles. The maximum water level, which is at the same time the pumping head, has been fixed at 5,600 ft. above sea level.

The dam will be of the cylindrical form, 115 ft. high. Its radius of curvature will be 755 ft. and its crest will be at an elevation of 5,600 ft. The 500 kVA transformer to be mounted there is fed by the Upper-Stage plant and transforms to low tension.

7. The 6·2 mile pressure tunnel has an inside diameter of 11·6 ft. and runs from the compensating basin to the surge tank. Several rivulets are diverted into this tunnel and diversion of the Lieser, which thus far has not been planned, may also be considered.

8. The surge tank has been designed as a two-chamber construction.

9. The pressure shaft leading to the Main Stage will have an inside diameter from 8·5 to 7·9 ft. and will consist of a steep section 5,740 ft. long, and a flat section 1,310 ft. long.

10. The underground power station of the Main Stage will have a rated capacity of 265 MW, based upon a utilisable water flow of 1,060 cusecs, a mean gross head of 3,620 ft. and a mean net head of 3,460 ft. Three horizontal generating units, of 100 MVA each, will be installed, and will be connected solidly with transformers which step up to 220 kV. For two of those three generating units pumps with starting turbines and clutches are envisaged. The power plant will be reached through an access gallery 1,650 ft. in length.

11. A tailwater tunnel and canal will convey the spent water to the Möll.

12. The intake in the Möll valley will have a maximum water level of 1,960 ft. and will consist of a settling tank with the necessary transfer pumps and transfer pipes to the underground power house.

The transfer pumping plant has been designed for a maximum capacity of 1,430 cusecs for a 33 ft. mean static lift and 1·8 MW mean pumping capacity; the mean energy factor is 0·0014 kWh per cu. ft.

13. The electrical facilities for energy transport will comprise a 110 kV underwater cable which is to be laid in the pressure tunnel and is to run from the Upper-Stage plant to the surge tank; a 110 kV underground cable over the steep slope to an outdoor substation; an outdoor substation for stepping up from 110 kV to 220 kV; and oil-filled cables between the 220 kV busbars of the underground power plant and the outdoor substation. From the outdoor substation a double 220 kV transmission line with bundled conductors will run through the middle section of the Möll valley to the Lienz transformer station.

The division of the plant into an Upper Stage and a Main Stage has been prompted by the following reasons. The pressure tunnel is considerably relieved by the auxiliary reservoir and the Upper-Stage plant, and further considerable relief is also afforded by creating the Gösskar compensating basin, the headwater conduit and the surge tank. This arrangement creates the possibility of diverting many small streams which would otherwise run to waste, and the division of the project facilitates the construction work in as much as it makes it possible to adapt the building programme more readily to the capital available.

In case of a one-stage plant the internal pressure in the headwater tunnel would run up to 357·5 lb. per sq. in., which would require costly steel linings where the rock cover is thin or the rock fractured. In the two-stage plant, however, the internal pressure is only 114·4 lb. per sq. in. so that whereby the extent of insufficient coverage is greatly reduced and a steel lining only required in the immediate neighbourhood of slopes.

(Continued on page 231)

Fig. 1. Cordtex layout for a shot at the Waipapa hydro-electric project

Paddock Blasting in New Zealand

A technique is described for blasting relatively large areas to comparatively shallow depths, which has been widely used by the New Zealand Ministry of Works

By G. J. HALLEWELL, A.M.I.C.E., A.M.I.Struct.E ,
Chief Construction Engineer

PADDOCK blasting is used for rock excavation and is descriptive of the method adopted. It means blasting of relatively large areas of shallow depth to produce material for excavation by mechanical equipment. The method has been used extensively in New Zealand by the Ministry of Works, which has now accumulated a considerable volume of experience in this work. The method has been developed from the need to keep relatively small mechanical shovels in full employment in restricted areas, and has been derived to suit available equipment and explosive materials. Probably it differs little from methods used in other countries except for extensive use of cordtex.

Mainly because of bridge weight limitations and railway clearance gauges the largest shovels that can be moved in New Zealand without major dissembly are of $\frac{3}{4}$ cu. yard capacity. The largest shovels in general construction use, of $2\frac{1}{2}$ cu. yard capacity, have to be stripped to be moved, and therefore are used on the larger jobs only. The size of excavator meant that a working face between 10 ft. and 20 ft. high gave best loading conditions and dictated depth of blast-holes. This depth in turn was beyond the reasonable capacity of jackhammers and made wagon drills necessary. In suitable rock, blasting has produced a product removable by scrapers direct plus pushers.

Up till recently wagon drills have been moved by manpower, light tractor or winch, and have mounted $3\frac{1}{2}$ in. drifters using $1\frac{1}{4}$ in. round steel forged in a single length with leyner lug shanks and taper fitting bits. Most wagon drills had 10 ft. slides and about 9 ft. steel changes. To drill a 15 ft. hole, an 18 ft. and a 9 ft. steel would be required. As an 18 ft. steel was as much as one man could handle, this limited the normal depth of hole to 15 ft.

Tungsten-Carbide Bits

Both tungsten-carbide bits or throw-away one-use bits were used, depending on the rock conditions. In broken soft ground throw-away Simplon bits gave

cheapest and best results, but in harder rock where 9 ft. could not always be obtained with a single throw-away bit tungsten-carbide bits were often used. The bulk of drilling for paddock blasting, however, has been with tungsten-carbide bits.

Drilling of blast holes has always been the weakest link in paddock blasting, as trouble has been experienced at various times with types and sizes of bits, method of fitting on the tapers, type and treatment of the various alloy steels experimented with, and getting stuck steels out of the ground. Each new job brought up these separate problems in a new form which needed to be overcome.

Crawler Drills Praised

At present the New Zealand Ministry of Works is satisfied that the most suitable drilling equipment is the crawler-type wagon drill moving on air-powered tracks and capable of towing a 600 c.f.m. compressor. These new drills mount 4½ in. drifters requiring a lot of air, but are capable of an equivalent amount of work, and can clear very deep holes provided there are adequate centre holes, of, say, 7/16 in. or even ½ in. diameter, in the hollow drill steel.

This has been very evident at the Ohakuri power project where the silicified breccia has pockets of unsilicified soft material which blocks conventional wagon drills very easily when boring wet, but through which the track drills, boring dry, pass with the greatest ease. One track drill will outdrill four or five conventional wagon drills.

The new track drills have their problems, too, and operate most successfully with coupled steels. The coupled steels are threaded and joined by standard sockets and the special leyner shanks. The special bits are adapted to the same thread. Ten-foot steels are the standard length used.

Both the 600 series thread and the 1½ in. rope thread have been tried with 1½ in. diameter leyner shanks and tungsten-carbide bits with female thread and in sizes from 2¾ in. to 3¼ in. The diameter of the sockets limits the minimum size of bits.

American 1¼ in. hexagon carburised drill steel has been used very successfully, and based on this experience all forging or turning work is being avoided by the use of jointed steels purchased fully manufactured. The use of alloy steels and the impossibility of getting skilled blacksmiths has made this almost essential now. An alloy steel capable of being machined is found equal to the carburised steel.

With these heavier drills threaded bits are favoured rather than the tapered-connection type, which, however, are reasonably satisfactory with the lighter drifters and 2¼ in. tungsten-carbide bits. These heavier drills can drill to 50 ft. but paddock depths of 15 ft. to 20 ft. are still preferred, as they produce a rock pile not too high for the shovels to work safely and easily. For best working conditions the rock pile should not be higher than the shipper shaft.

The powered movement and powered positioning and moving of the drifter and slide in these track drills is extremely convenient in practice, and an absolute necessity with the heavier equipment now used.

In hydro-electric work excavation to accurate dimensions and levels is frequently essential. Often each cubic yard of rock excavated beyond specified lines has to be replaced by a cubic yard of concrete. Even more important, rock outside the neat lines must not be disrupted. This accuracy of excavation has been best met by paddock blasting with each batter line accurately set out with surveying instruments and each shot-hole position closely located. In addition, depths of holes need survey control to produce good working conditions on the lower bench or to prevent damage below grade. Where possible datum lines are established and used to check each drill hole for depth, this is the best assurance of a good working floor for shovel and rock wagons.

Line Drilling Effective for Trimming

In rock which cannot be trimmed easily by pneumatic pick it has been found that line drilling along the outer perimeters is the best substitute and quite effective except in very jointed rock. This method of trimming batters is one that suits New Zealand's economic conditions but may not apply universally.

Line-drilled holes need not always be very close. While 6 in. centres are necessary in some rocks, in others holes at 2 ft. or even 5 ft. centres, if drilled accurately, produce a clean uniform batter. In narrow confined excavations the amount of drilling in line-drill holes can easily be double that required for placing explosives.

Explosive demand has usually been between 0·5 lb. and 0·75 lb. per cu. yard of solid rock excavated. Explosives used have always been ammonium nitrate polar 50%, or 60% gelignite, or gelatine dynamite. It is supplied usually in cartridges but sometimes in granular form in 50 lb. cases.

Where possible, the cartridges supplied have been about ¼ in. less in diameter than the nominal diameter of the drill hole and as long as possible to save time in hole loading. Moderate tamping of the explosive with wooden tamping sticks has always been practised, and holes have always been closed with dry, free-running sand or silt. Holes would normally be about half to two-thirds filled with explosives.

Over the past 15 years Primacord or cordtex detonating fuse has been available, and over the last ten years millisecond-delay blasting has been employed, first by the use of millisecond-delay detonators, next by use of the sequence switch, and lately by use of cordtex delays. Initially the slight delay in cordtex itself was used to give a relieving action in a large blast, but millisecond-delay blasting has given an enormous increase in control and in the reduction of shattering effect outside the area to be blasted.

Minimum Number of Detonators

The use of electric detonators at the bottom of a column of explosive is widely advocated by some authorities and has considerable merit, but the Ministry of Works method has been consistently to avoid detonators in the ground and to reduce their use to a minimum in the interests of safety. With cordtex delays, only one detonator, tied on at the last moment to initiate the cordtex, is required.

Detonation by cordtex requires a branch to be taken to the bottom of each shot hole. This is done by using the first cartridge as a primer and lowering it down the hole with the cordtex.

A primer is made up by making a diagonal hole in the cartridge with a wooden skewer, passing the cordtex through, and securing it with a thumb knot.

Fig. 2. Rock pile heaped in the centre of the cutting

Fig. 3. The clean batter produced by the shot depicted in Fig. 2.

The cordtex and cartridge are then lashed securely with two or three turns of twine round each end of the plug.

Each branch of cordtex is tied to the cordtex main with a clove hitch pulled tight and the loose end tied back on to the branch with binding wire or tape. The mains in turn are led to the detonating point where the delays, either electrically with the switch, by delay detonators, or by cordtex delays, are introduced. Cordtex delays are now normally used in preference to either of the other methods. Mains and branches are joined by binding the two together for about 6 in. with insulation wire or tape or by a reef knot plus binding. The direction of initiation must be studied, as the branch must take off in the direction of initiation; otherwise it can be cut off and not detonate.

The laying of mains needs to be properly engineered to get the best results from the millisecond delays introduced into the blast. The effect of this type of blasting is for the rock pile to travel towards the point of zero delay, and if this is not desired a definite pattern should not be used. In blasting a long, deep, narrow channel, for example, the main carrying a zero delay is laid along the long central axis and each successive delay is applied to a similar pair of mains lying parallel on either side of the centre main. Delays come in succession until the batter line is reached. This method produces a rock pile heaped in the centre of the cutting and a clean batter (see Figs. 2 and 3).

Secondary Shooting Eliminated

By careful and symmetrical placing of blast holes, it has been found that secondary shooting can be eliminated.

For ease of setting out, a simple rectangular pattern is usually employed, with spacings longitudinally and transversely varying from about 4 ft. to 8 ft. as found necessary for best results. At Roxburgh, in quartz schist, holes had to be kept more than 6 ft. apart to avoid sympathetic detonation, and a diagonal pattern was adopted to get greater hole separation.

To ease the shock on the batters it is normal practice to reduce the charge to about half to two-thirds in the last row of holes before the batter and to reduce the burden accordingly. Batter trimming holes are assisted by reducing the burden to 3 or 4 ft. and loading holes at about that spacing along the batters. Only about one fifth full charge is required in each hole, and cartridges are spread through the hole by deck loading to avoid damage by concentrations of charges and to give the widest scattered effect while making sure that the toe comes away. Inclined batters have been line drilled, but the vertical stepped batter is easier to set out and control.

Blasting charges in paddock blasting have been varied to suit conditions, but the largest possible are recommended, because there is generally no increase in blast damage with size since the area involved increases directly as the charge, and the fewer the blasts the fewer the delays in clearing the area and reinstating it afterwards. Hydro-electric works are usually well clear of other works or habitation in New Zealand, and convenience is generally the criterion. Blasts have normally varied from about 2,000 to 10,000 lb of explosive.

Control has usually been such that inclined ramps have been formed, as work progresses downward, by controlled drilling, leaving the ramps in solid. In the solid, ramps as steep as 1 in 5 are practicable, but not recommended where flatter ramps are possible.

When making these large blasts strict control is necessary to ensure that danger areas are cleared and kept clear of personnel. Electric detonation is favoured; it is more closely under control and can be done instantly the all clear is received. Detonation by safety fuse, however, is simple and quite often used.

Faultless Setting Out Essential

The method of detonation of a system of mains and branches in cordtex means that the cordtex must be faultlessly set out and tied up; otherwise a whole section can misfire. If a break does occur in the cordtex, nothing will detonate beyond the break.

This is the disadvantage of this system and it is why many prefer electric detonators down the hole, for with electric detonators, given sound wiring and ample current, once the circuit is closed all detonators must explode. For this reason checking of all cordtex knots and connections is essential. All mains and branches should be tight and neat, but not tight enough to break any joints, and all cordtex should be examined by touch for breaks that occur in manufacture. These are always large enough to be felt. In wet holes, cut ends of cordtex should be waterproofed to avoid failure due to deterioration of cordtex. Methods of making connections and avoiding sharp bends are now standardised and should be followed meticulously. While tying up is in progress all unnecessary traffic should be prohibited in the paddock.

Fig. 4. Wagon drills at work on a typical paddock blasting operation for the Waikato scheme

Fig. 5. Placing and tamping explosives

When this method was first introduced at Roxburgh misfires were common. The cause was traced to sympathetic detonation, which was cured primarily by respacing drill holes and use of a sequence switch. Occasionally there would be an electrical fault. Misfires are no longer experienced, because of use of cordtex delays, sound practice in making cordtex connections, and careful checking.

It is considered that cordtex gives better use of the explosive and better fragmentation than do electric detonators in the primers. As no detonators are attached until a few minutes before detonation, the method is eminently safe, even if misfires do occur and free explosives are left in the rock pile.

It is quite impossible to detonate cordtex except with a detonator. The Department often uses two detonators together to be sure there is a detonation. There was at least one failure before this was done.

Proven Maxims

In the early days when the sequence switch was first used, considerable study of ground shock amplitude and the effect of interference of successive shots was made, using geophones and a vibrograph. This work confirmed what is now generally accepted—that the maximum ground shock is generally not much more than that due to the separate charge set off by each delay, and that in a certain rock and for a certain

Fig. 6. Firing the shot seen in Fig. 1

Fig. 7. The clean result of the shot

pattern of holes there is an optimum value of the delay interval giving most interference and least shock. At Roxburgh with 7 ft. spacing and in mica-schist, this time interval was 15 to 20 millisec. Variation of this interval was possible with the sequence switch, but it was otherwise rather delicate for its purpose. The 17 millisec. of the cordtex delay has been found good enough for general work and otherwise much more convenient.

Where electric detonators are used the Department believes in checking all detonators before use, and also in using an electrician or specially skilled man to tie up and check all connections and circuits.

With reasonably good equipment it has been found possible to excavate at about 5,000 to 10,000 cu. yards of rock per face per shift per month.

Paddock-blasting methods have been used at Kaituna, Roxburgh, Hawea, Waitaki, Waipapa, and Ohakuri power projects by the New Zealand Ministry of Works' own forces. They will be employed on the new Benmore project where between two and three million cubic yards of rock excavation is required. For this scheme there has been an increase in equipment size to 4 cu. yard shovels, 16 cu. yard rock wagons and heavy-duty crawler wagon drills throughout.

Experience Summarised

Ministry of Works experience can be summarised as follows:—

1. Holes should be deep enough to produce a rock pile as high as the shovel's shipper shaft.
2. Holes should be reasonably closely spaced to avoid oversize fragments, but should not be close enough to induce sympathetic detonation. This could be as far as 6 ft. or even 7 ft. in certain rocks.
3. Holes should be drilled to a definite pattern, set out on the ground with each hole clearly marked; to a definite depth, by use of a string line or similar device.
4. Cordtex system should be planned and delays used to move the rock in a definite pattern.
5. All detonators, electrical circuits and cordtex connections should be double checked.
6. Line drilling is often quicker and cheaper than batter trimming and is quite accurate if properly set out.
7. Cordtex for detonation is favoured because detonators are kept out of the ground, and also because its high-speed detonation gets the best out of the explosives and improves fragmentation.
8. By careful planning, secondary blasting should be practically eliminated and excavation be a continuous operation.

A Typical Blast Record

The following is a record of a typical paddock blast at Roxburgh:—

No. of holes loaded (6 ft. c/c. in rows): 504.
No. of rows at 7 ft. c/c.: 18 at one end, 20 at other (change in section).
Depth of holes: 15 ft. (few 18 ft.); diameter of holes: 2¼ in.
Explosive used: 7,200 lb. gelatine dynamite.
Production of blast in cu. yards solid: 10,000 cu. yards plus.
Explosive per cu. yard: 0·70 lb.
Footage drilled including line holes: 10,800 ft.
Cordtex used: mains 3,400 ft., branches 9,100 ft., total 12,500 ft.
Cordtex per cu. yard: 1·2 ft; per lb. explosive: 1·75 ft.
No. of delays: 9; time interval: 0·025 sec.; overall: 0·225 sec.
Line holes at 6 in. c/c. every fifth deck loaded with 3–4 lb. explosive.
Easer holes 4½ ft. from line holes loaded with 7 lb. explosive.
Main holes had 16 or 17 lb. per hole.
Connecting wires P.V.C. 1/·044.
Firing cable twin yellow No. 2—500 yards.
Resistance of cable: 25 ohms; of sequence switch: 15 ohms; wire and detonators in each circuit: 5 ohms; total 45 ohms.
Firing by lighting set plus battery charger adjusted to give 48 V at firing switch, current 1 A plus.

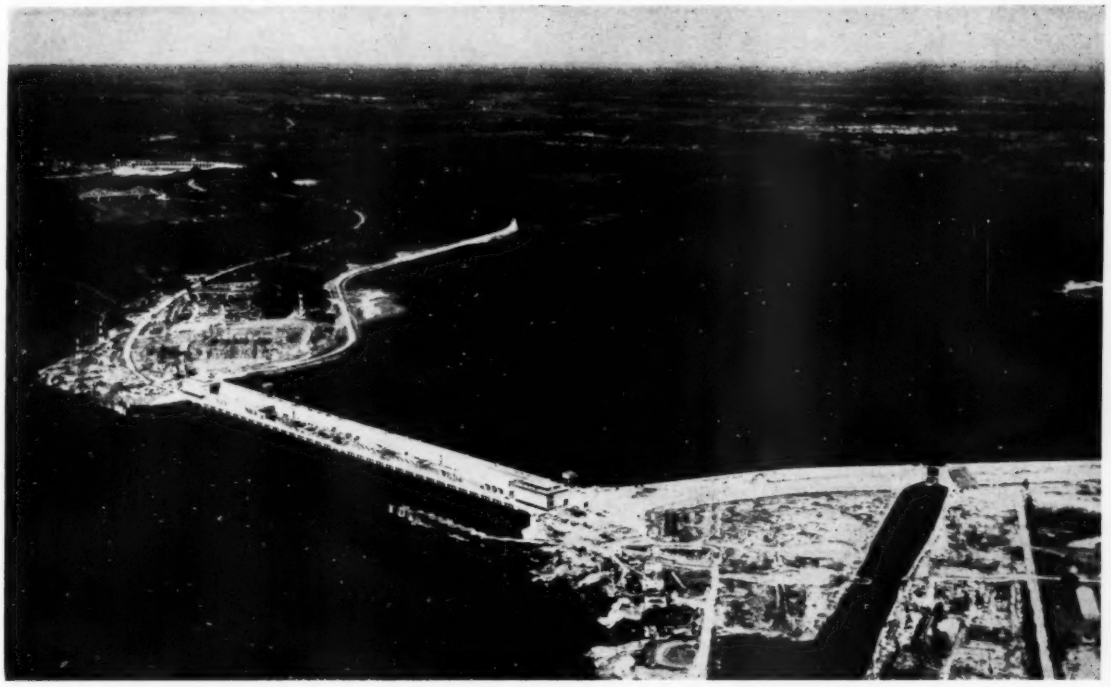


Fig. 1. The power houses on the St. Lawrence River

Controlling the St. Lawrence River for Power

By IRA A. HUNT, Jr., Major, Corps of Engineers, U.S. Army,
District Engineer, U.S. Lake Survey, and Chairman,
United States Section, Working Committee of the International St. Lawrence River Board of Control

ON September 5, 1958, dignitaries from the United States and Canada assembled at the Moses-Saunders power houses in the International Rapids section of the St. Lawrence River to witness the inauguration of the hydro-electric power generating project. The feat of harnessing the river at this site had been completed in less than four years from the ground breaking—a feat made all the more remarkable considering that during the entire construction period the 14 ft. navigation facilities had to be kept open and the water levels of the St. Lawrence River and Lake Ontario had to be maintained at what they would have been under natural conditions. To many of the observers, this great accomplishment was a dream of many years come true; it was a herculean task well done and an epic of international co-operation.

The governments of the United States and Canada designated the Power Authority of the State of New York and the Hydro-Electric Power Commission of Ontario to construct, maintain, and operate the proposed works. The total costs of the works, including certain navigational improvements, were to be divided equally between the two constructing entities. These costs are estimated to be $500,000,000. The major construction works undertaken by the power entities included the power-house structures, Long Sault spillway dam and Iroquois dam, dikes for retaining the power pool, and channel enlargements for power and navigational purposes, Figs. 2 and 3.

The power dam spans the channel between the eastern end of Barnhart Island and the Canadian shore. The structure is bisected by the International Boundary, with the Robert H. Moses power house on the New York side and the R. H. Saunders-St. Lawrence generating station on the Ontario side. The power structure is 3,300 ft. long with a head of 83 ft., and when completed it will have 32 turbines develop-

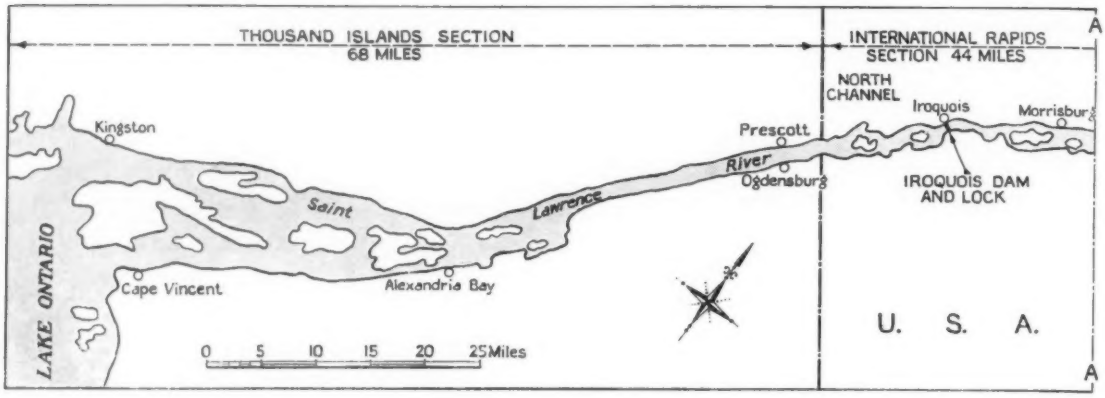


Fig. 2. Power and navigation improvements on the St. Lawrence River

ing 2·2 million horsepower, Fig. 1. On January 1, 1959, 16 of the 32 units were on the line and producing.

The two control dams are located upstream of the power houses. Long Sault spillway dam, an attractive curved structure some 2,250 ft. long with thirty 50 ft. wide spillway sections, was built from the upper end of Barnhart Island to the New York State mainland, and lies entirely within the United States (Fig. 6). Long Sault dam controls the elevation of the power pool and affords a bypass for emergency operations. Iroquois Dam, a buttressed gravity dam with 32 fixed-roller vertical lift gates operated by two 350 ton gantry cranes, was built 29 miles upstream from the power houses to control the outflow, and consequently the levels, of Lake Ontario, Fig. 4.

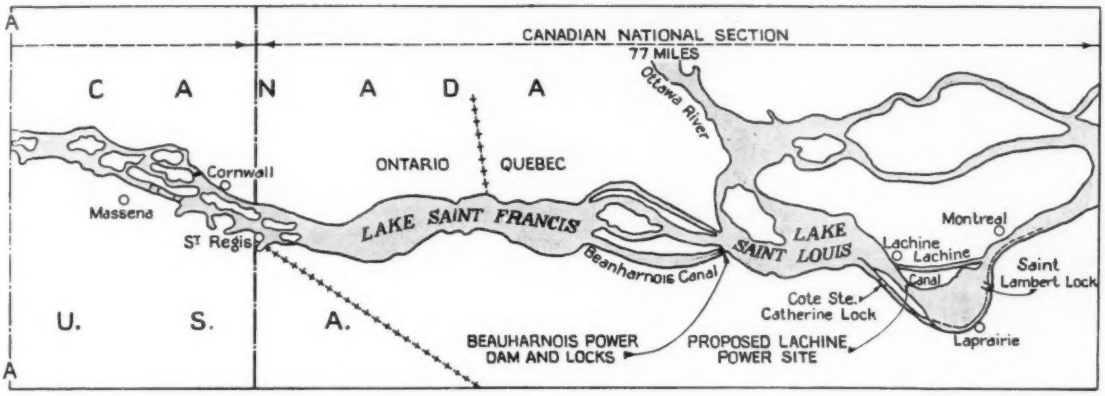
The large differential heads caused by the dams were overcome for navigational purposes by the construction of three locks and a canal. Iroquois lock, at the Canadian end of Iroquois dam, provides a 4 ft. lift under normal circumstances and affords a bypass around the dam. The ten-mile long Wiley-Dondero canal, on the United States side of the river, furnishes passage for the vessels to and from the power pool which is now known as Lake St. Lawrence. Excavation for this canal necessitated the removal of over 16,000,000 cu. yards of tough glacial till and marine clay. The Bertrand H. Snell and Dwight D. Eisenhower locks are located in the canal; each provided an approximate 40 ft. lift. The Snell and Eisenhower locks and the Wiley-Dondero canal were constructed by the Corps of Engineers, United States Army, for the St. Lawrence Seaway Development Corporation.

In constructing the power project, tens of millions of cu. yards of materials were excavated and over two million cu. yards of concrete were poured. Construction techniques between contractors in the United States and Canada varied considerably. For instance, American contractors poured their concrete in 5 ft. vertical sections generally in above freezing weather, whereas Canadian contractors poured monolithic structures in all kinds of weather. When considering the tremendous scope of the project, it is no wonder that the Hydro-Electric Power Commission of Ontario and the Power Authority of the State of New York take just pride in the completion of their joint endeavour. As a testimonial to this splendid co-operative effort, the two power entities plan to construct a plaque over the International Boundary at the centre of the power-house structure which will be inscribed with the following words:

"This stone bears witness to the common purpose of two Nations, whose frontiers are the frontiers of friendship, whose ways are the ways of freedom, and whose works are the works of peace."

To construct the works for the development of power in the International Section of the St. Lawrence River, the Governments of Canada and the United States applied to the International Joint Commission for an order of approval. It is in the work of the International Joint Commission that perhaps the most important story of international co-operation with regard to the use of the international waters of Lake Ontario and the St. Lawrence River is found. The Commission was established by the Treaty of 1909 between Canada and the United States to regulate levels, diversions, obstructions, or pollutions of boundary waters and of waters flowing across the boundary. It was designed to settle peacefully and amicably all United States-Canadian water-boundary controversies involving the rights or interests of the inhabitants of either country, and it was accordingly granted quasi-judicial powers to settle such problems by international judicial arbitration. Each country has three representatives on the Commission. At the present time, the Canadian chairman is General A. G. L. McNaughton, former Chief of Staff of the Canadian Army, with Mr. Lucien Dansereau and Mr. Donald McGregor Stephens as Commissioners, and the American chairman is Governor Douglas McKay, former Secretary of the Interior, with Mr. Eugene W. Weber and Mr. Francis L. Adams as Commissioners.

In the order of approval for the development of power at the International Rapids Section of the St. Lawrence River, given on 29 October, 1952, by the International Joint Commission, the International St. Lawrence River Board of Control was established. Upon completion of the power project, this Board of Control, consisting of an equal number of representatives of each nation, was to see that the discharge of water from Lake Ontario and the flow of water through the International Rapids Section be so regulated as not to conflict with or restrain the uses of water of the St. Lawrence River for purposes given preference over the uses of water for power purposes by the Treaty, namely, uses for domestic and sanitary



purposes and uses for navigation; to see that the works are operated in such a manner as to safeguard the rights and lawful interests of others engaged in the development of power in the St. Lawrence River below the International Rapids Section; and to see that the works are so operated as to safeguard as far as possible the rights of all interests affected by the levels of the St. Lawrence River upstream from the Iroquois regulatory structure and by the levels of Lake Ontario and the lower Niagara River.

The Board of Control consists of four members from each country. The chairman of the American section is Major General Louis J. Rumaggi, Division Engineer, North Central Division, U.S. Army Corps of Engineers, with Colonel Arthur C. Nauman, Washington, D.C., Mr. J. B. McMorran, and Mr. W. R. Farley, as members. The chairman of the Canadian section is Mr. T. M. Patterson, Director, Water Resources Branch, Department of Northern Affairs and National Resources, Mr. D. M. Ripley, Mr. J. B. Bryce, and Dr. René Dupuis, as members.

From the dictates of the International Joint Commission to the Board of Control, it can be seen that many interests must be served and protected in the operation of the works at the International Rapids Section. In a Supplementary Order to the Order of Approval dated 2 July, 1956, the International Joint Commission set forth the basic requirements for a plan of regulation for Lake Ontario in the form of a set of criteria which are primarily a range of stage and limiting conditions for Lake Ontario levels and outflows. Utilising these criteria, the Working Committee of the Board of Control formulated the Lake Ontario Regulation Plan. In the development of this plan, data for the period of record 1860 to 1954 were used. Ultimately, it was adopted by the International Joint Commission as the initial operating plan of regulation, with provisions made for adjustments and progressive improvements as operating experience is gained.

Properly to understand the significance of the criteria for regulation set forth by the International Joint Commission, it would be well to present a brief summary of the hydrology of Lake Ontario and the St. Lawrence River. Lake Ontario, the lowermost in the Great Lakes chain, is also the smallest. It has a drainage area of 34,800 sq. miles, of which 7,500 sq. miles are water surface area. The level of Lake Ontario varies both annually and seasonally. The average level of Lake Ontario at Oswego, New York, for the period 1860 to 1954 is elevation 246·04 ft., United States Lake Survey 1935 Datum. The monthly mean level of the lake has varied from a low elevation of 242·68 ft. for November 1934 to a high elevation of 249·29 ft. for June 1952, making a total range in monthly mean stage of 6·61 ft.

In addition to these variations over the long term, the levels of the lake show a seasonal pattern of high stages in the spring and summer and low stages in the fall and winter, the average range from high to low being 1·8 ft. The outflow of Lake Erie, which drains an area of 260,000 sq. miles through the Niagara River and Welland canal, contributes 85% of the net total supplies to Lake Ontario. This flow into Lake

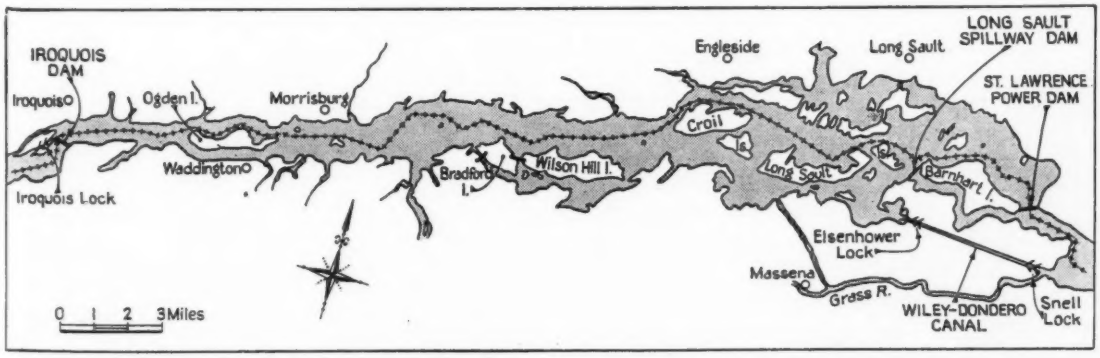


Fig. 3. Map to an enlarged scale of the International Rapids Section

Ontario varies slowly from month to month so that any rapid change in the average lake level results from unusual net basin supplies. The net basin supply to Lake Ontario is comprised of the precipitation falling on the lake surface P plus the run-off from the land drainage area R minus the evaporation E. The average monthly values of the factors comprising the net basin supply along with the average monthly change in lake storage S_{1-2}, and the average monthly differences between outflow of the St. Lawrence O_{1-2} and the inflow from Lake Erie I_{1-2} for the period 1934 to 1952 are shown in Table I, in feet on Lake Ontario. Note the very high run-off in March and April due to snowmelt, the relatively constant precipitation, and the high evaporation rates in the fall and low evaporation rates in the spring.

Before the construction of the St. Lawrence power and seaway projects, the outflows of Lake Ontario were controlled by a rock outcrop in the Galop Rapids reach of the St. Lawrence River. Thus, there was a definite relationship between the level of Lake Ontario and the outflow of the St. Lawrence River which held in all periods except under ice conditions. The formation of ice in the reach of the river above the International Rapids Section has as its direct result the diminution of flow from Lake Ontario. Therefore, for the same Lake Ontario stage, the flow would be less during periods of ice than it would be under open water conditions. The outflows of Lake Ontario have been regulated by the Iroquois dam since December 1956. At the present time (January 1, 1959), the flows in the river are regulated so that they are the same as they would have been in nature had not the construction of the power and seaway projects been undertaken—the so-called preproject levels.

The water levels and flows in the St. Lawrence River downstream from the power houses, in the Canadian National Section, are complicated by the flow of the Ottawa River into Lake St. Louis above Montreal, and by the formation of ice in Montreal harbour. The maximum and minimum daily inflows to Lake St. Louis from the Ottawa River have been 190,000 cusecs and 3,000 cusecs. In the winter, the water level in Montreal harbour normally rises from 11 to 22 ft. due to ice retardation and during a severe ice jam, it has risen as much as 32 ft. above low water level.

From the above resumé of the hydrology involved, the necessity for considering the rights of riparian, navigation, and power interests, both above and below the International Rapids Section, can be easily understood. To this end, criteria—each of which affected all interests to a varying degree—were established by the International Joint Commission and incorporated into the Lake Ontario Regulation Plan by the Working Committee of the International St. Lawrence River Board of Control. A brief discussion of each criterion, its primary beneficiaries, and some of the results obtained from the regulation plan are given below.

Criterion (a): *The regulated outflow from Lake Ontario from 1 April to 15 December shall be such as not to reduce the minimum level of Montreal Harbour below that which would have occurred in the past with the supplies to Lake Ontario since 1860 adjusted to a condition assuming a continuous diversion out of the Great Lakes Basin of 3,100 cusecs at Chicago and a continuous diversion into the Great Lakes Basin of 5,000 cusecs from the Albany River Basin. (Hereinafter called the "supplies of the past as adjusted.")*

This criterion is primarily to protect downstream navigation and riparian interests. It also affects the distribution of minimum flows which, in turn, is of importance to all power interests. The concept of supplies of the past as adjusted is important. At the present time, approximately 5,000 cusecs are diverted by Canada from the Hudson Bay watershed into Lake Superior and 3,100 cusecs are diverted from Lake Michigan at Chicago for sanitary and navigation purposes into the Mississippi River watershed. Thus, the net diversion is 1,900 cusecs into the Great Lakes. Although the diversion figures have varied in the past, the present diversions control the over-all effect on Lake Ontario levels, which is a raising of almost 0·09 ft.

Criterion (b): *The regulated winter overflows from Lake Ontario from 15 December to 31 March shall be as large as feasible and shall be maintained so that the difficulties of winter power operation are minimised.*

Criterion *(b)* is of primary benefit to power. The outflows should be as large as feasible during the winter because it is during this period that the maximum demands for power must be met. Nevertheless, it is imperative that the flows be regulated to permit the formation of an ice cover at the power pool to eliminate the damaging effect of frazil (ice crystals within a body of water). A flow of 220,000 cusecs or less is necessary to allow the formation of ice. To ensure that the ice cover remains intact, the weekly variation in flow should be limited to 20,000 cusecs. However, increased flows or substantial variations in

TABLE I.—AVERAGE MONTHLY VALUES OF THE HYDROLOGIC FACTORS, IN FEET, AFFECTING LAKE ONTARIO LEVELS FOR THE PERIOD 1934–1952

$$S_{1\text{-}2}=P_{1\text{-}2}+R_{1\text{-}2}-E_{1\text{-}2}+(I_{1\text{-}2}-O_{1\text{-}2})$$

1	2	3	4	5	6
Month	$S_{1\text{-}2}$	$P_{1\text{-}2}$	$R_{1\text{-}2}$	$E_{1\text{-}2}$	$(I_{1\text{-}2}-O_{1\text{-}2})$
January ...	+0·15	0·20	0·46	−0·19	−0·32
February ...	+0·16	0·17	0·41	−0·10	−0·32
March ...	+0·57	0·20	0·79	−0·06	−0·36
April	+0·60	0·17	0·97	−0·04	−0·50
May	+0·27	0·20	0·59	−0·04	−0·48
June	0·00	0·18	0·30	0·00	−0·48
July	−0·23	0·10	0·19	−0·11	−0·50
August ...	−0·46	0·14	0·14	−0·28	−0·46
September ...	−0·38	0·20	0·15	−0·32	−0·41
October ...	−0·36	0·20	0·20	−0·38	−0·38
November ...	−0·15	0·23	0·29	−0·35	−0·32
December ...	−0·06	0·22	0·36	−0·34	−0·30
Total	+0·11	2·30	4·85	−2·21	−4·83

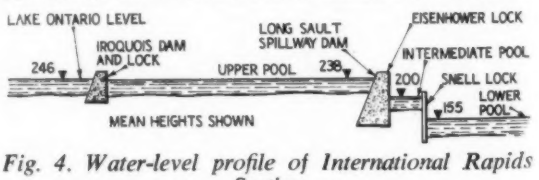


Fig. 4. Water-level profile of International Rapids Section

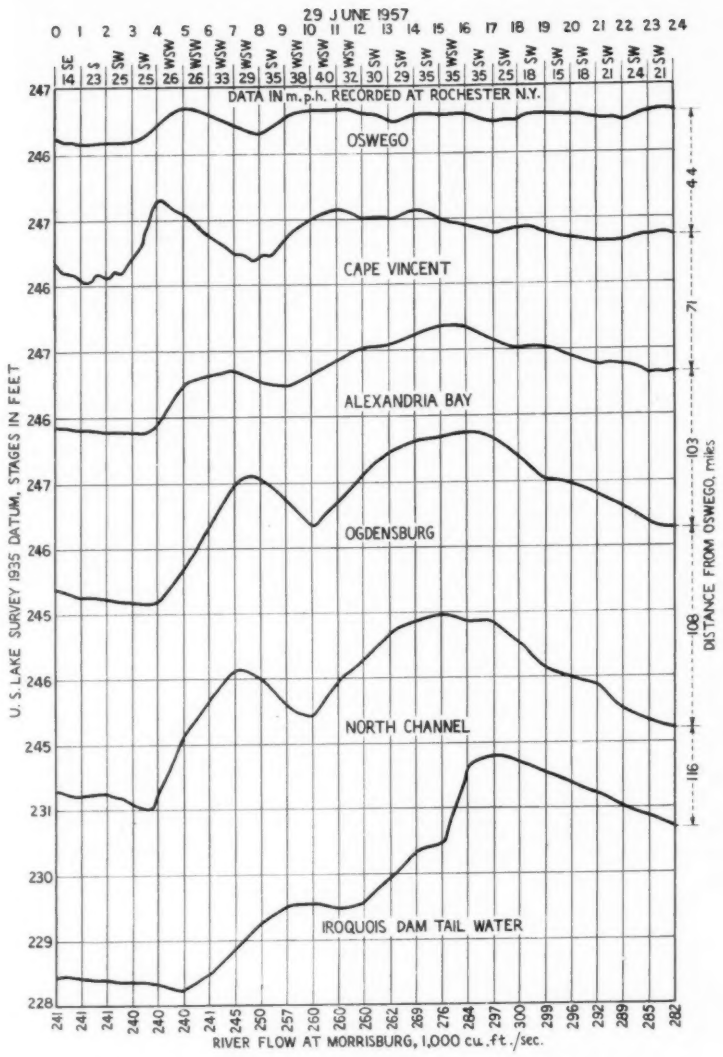


Fig. 5. Example of a storm surge on the St. Lawrence

flows during the winter period may augment the flood hazard in the Montreal area.

Criterion (c): *The regulated outflow from Lake Ontario during the annual spring break-up in Montreal Harbour and in the river downstream shall not be greater than would have occurred assuming supplies of the past as adjusted.*

This criterion takes into consideration the downstream riparian interests. The ice break-up period in Montreal harbour is critical. As mentioned previously, ice jams have caused a rise as high as 32 ft. above low water in the past.

Criterion (b): *The regulated winter outflows from Ontario during the annual flood discharge from the Ottawa River shall not be greater than would have occurred assuming supplies of the past as adjusted.*

Criterion *(d)* was included to protect the riparian interests on Lake St. Louis, in Montreal harbour, and on the river downstream. The flood discharge of the Ottawa River has had a great influence on flood levels; however, more and more control dams have been built on the Ottawa and the threat of flooding greatly reduced.

Criterion (e): *Consistent with other requirements, the minimum regulated monthly outflows from Lake Ontario shall be such as to secure the maximum dependable flow for power.*

The power entities in the International Rapids Section indicated that their anticipated power demands necessitated flows which are a minimum in the summer and a maximum in the winter. The relative magnitude of the specified minimum outflows of the Lake Ontario Regulation Plan were designed in so far as possible to vary in accordance with these anticipated demands. The minimum summer outflows were set to maintain minimum water levels on Lake St. Louis and downstream.

Table II compares the minimum outflows of the plan and the minimum recorded adjusted outflows.

Criterion (f): *Consistent with other requirements, the maximum regulated outflow from Lake Ontario shall be maintained as low as possible to reduce channel excavation to a minimum.*

The channel excavations were carried out to provide the stipulated depths and velocities for navigation based on the critical design conditions of a preliminary version of the regulation plan. The outflows of the Lake Ontario Regulation Plan were designed to meet the velocity-stage criteria for these channels.

Criterion (g): *Consistent with other requirements, the levels of Lake Ontario shall be regulated for the benefit of property owners on the shores of Lake Ontario in*

TABLE II.—MINIMUM OUTFLOWS FROM LAKE ONTARIO (1,000 CUSECS), JUNE 1860–DECEMBER 1954

Month	Recorded adjusted to present conditions	Under Lake Ontario regulation plan
January ...	176	210
February ...	164	212
March	188	207
April	197	190
May	204	190
June	209	196
July	206	195
August ...	197	195
September ...	190	190
October ...	186	190
November ...	180	200
December ...	180	210
Average ...	189·8	198·8

the United States and Canada so as to reduce the extremes of stage which have been experienced.

The extremes of stage are of great importance to riparian interests on Lake Ontario. The extreme recorded monthly mean levels, the extreme recorded adjusted monthly mean levels, and the extreme recorded adjusted monthly mean levels under the Lake Ontario Regulation Plan for the period 1860-1954 are given in Table III. It can be seen that the difference between the extremes of stage is greatly reduced.

Criterion (h): *The regulated monthly mean level of Lake Ontario shall not exceed elevation 248·0 with the supplies of the past as adjusted.*

This criterion is, of course, to reduce the property damage that invariably results when there are extremely high stages. Routing the supplies of the past in accordance with the Lake Ontario Regulation Plan, the maximum monthly lake level elevation exceeded 248·0 ft. by 0·08 ft.; however, positive steps are being taken to amend the rule so that this elevation is not exceeded in actual operation.

Criterion (i): *Under regulation, the frequency of occurrences of monthly mean elevations of approximately 247·0 and higher on Lake Ontario shall be less than would have occurred in the past with the supplies of the past as adjusted and with present channel conditions in the Galop Rapids Section of the St. Lawrence.*

The action of the waves on the shore when beaches are flooded because of high lake levels creates damage, but it is the ultimate storm water levels resulting from wind set-up and wave up-rush superimposed upon high average lake levels that cause the extreme damages. Therefore, it is important that the frequency of high lake levels under the plan of regulation be reduced so that there is less chance of major storms causing havoc. The frequency of occurrences above elevation 247·0 ft. has been reduced in the Lake Ontario Regulation Plan during the usual storm periods.

Criterion (j): *The regulated level of Lake Ontario on 1 April shall not be lower than elevation 244·0. The regulated monthly mean level of the lake from 1 April to 30 November shall be maintained at or above elevation 244·0.*

This criterion safeguards the rights of navigation, which by virtue of the Treaty of 1909 has preference over power in the uses of water. The navigation season on Lake Ontario has been extended under the regulation plan to include the period 1 to 15 December. The Lake Carriers' Association, which has among its membership 30 fleets operating 96% of the total U.S. vessel capacity on the Great Lakes, in its notices of recommended drafts makes changes by the inch, depending upon current lake levels. Where inches count so much, it is important that during the navigation season the level of Lake Ontario be maintained at or above elevation 244·0 ft. (the low-water datum on Lake Ontario to which all dredging and channel improvements are referred).

Criterion (k): *In the event of supplies in excess of the supplies of the past as adjusted, the works in the International Rapids Section shall be operated to provide all possible relief to the riparian owners upstream and downstream. In the event of supplies less than the supplies of the past as adjusted, the works in the International Rapids Section shall be operated to provide all possible relief to navigation and power interests.*

The Lake Ontario Regulation Plan was based on utilising the supplies available in the period 1860 to 1954. Criterion *(k)* gives flexibility to any plan of regulation if the supplies in the future should be more critical than the supplies of the past.

The International Joint Commission has endeavoured to safeguard as far as possible the rights of all interests affected by the operation of the St. Lawrence projects. Any plan of regulation must of necessity be a compromise to satisfy the divergent priorities of upstream and downstream navigation and riparian and power interests. The plan of regulation as developed by the International St. Lawrence River Board of Control meets the stringent criteria of the International Joint Commission and takes into consideration the rights of all interests.

It is impossible to forecast all eventual supplies and contingencies with relation to the levels of Lake Ontario and the flows in the St. Lawrence River. There will be times when temporary deviations from any plan of regulation are necessary because of ice conditions, downstream flooding, and gravity surges. Although the pattern of flow may have to be varied to meet these conditions, the total volume of water discharged during a given period should equal the quantity contemplated by the plan of regulation. For instance, emergency measures will undoubtedly have to be taken to compensate for river surges caused by wind set-up on Lake Ontario. On 29 June 1957, during the construction period, a recorded wind set-up of only 0·5 ft. at Oswego caused a 3·6 ft. rise at Iroquois dam tail water. Such a gravity surge travels down-river at a speed of approximately 20 m.p.h. It can be seen from Fig. 6 that the St. Lawrence River discharge increased from 240,000 cusecs to 300,000 cusecs in a period of 12 hours. It takes "on the spot" operation to accommodate phenomena such as the wind surges within the framework of the more normal conditions on which the regulation plan is based.

Since the start of construction in August 1954, the levels of Lake Ontario have been compensated to

TABLE III. — MONTHLY MEAN WATER LEVELS OF LAKE ONTARIO (1860–1954) IN FEET ABOVE MEAN TIDE, NEW YORK

	Recorded levels	Recorded adjusted to present conditions	Recorded adjusted levels for navigation season under Lake Ontario regulation plan	Recorded adjusted levels for full year under Lake Ontario regulation plan
Maximum water level ...	249·29	248·93	248·08	248·08
Minimum water level ...	242·68	242·84	244·20	243·02
Range of stage, in feet ...	6·61	6·09	3·88	5·06

Fig. 6. Eisenhower lock with Long Sault spillway dam in the background

keep them at preproject conditions. Because of adroit planning and outstanding engineering, deviations from preproject levels have been small. When the St. Lawrence seaway and power project is completed and the Lake Ontario Regulation Plan goes into effect, riparian, navigation, and power interests can be assured that their individual rights have received the utmost consideration and that the water levels of Lake Ontario and the flows in the St. Lawrence River will be controlled for the equitable benefit of all.

NOTE. Figs. 1 and 6 are reproduced by courtesy of Ontario Hydro.

From page 219

The surge tank in a one-stage plant, that is for headrace conduit 13·6 miles long, would necessarily have a height of 720 ft. In the two-stage plant the headrace conduit proper is, as a result of the availability of the Gösskar storage reservoir, only about 6·2 miles in length and the surge shaft only about 330 ft. high.

As detailed measurements of the water supply indicate, the projected plant can be expected to yield a power production of 580 million kWh, 91% of which will be in the winter months. A major advantage of the project consists in the fact that the amount of winter energy obtainable from the new power plants on the Drau will be raised by 54 million kWh.

"Leading the World." This 64-page stiff-covered brochure issued by the British Electrical and Allied Manufacturers' Association may be regarded as a sequel to the Association's earlier publication, "Serving the World," produced for the occasion of the Brussels World Exhibition last year. Much of the brochure is devoted to an illustrated account of the BEAMA stand at the Exhibition—which, incidentally, included a large Kaplan runner and a model of one of the Priest Rapids sets—and of the British Electrical Conference held there. The papers presented by Sir Gordon Radley "Communication between Nations and Peoples" and by Sir John Cockcroft "Nuclear Energy—the Power of the Future" are reproduced in full. A further section recounts the British contribution to the Geneva "Atoms for Peace" Exhibition, and other sections discuss British electrical exports and summarise the work of the Association.

Brush and its Products. The Brush Electrical Engineering Co. Ltd. is now a member of the Hawker Siddeley Group and manufactures a wide range of electrical equipment—transformers, switchgear of both indoor and outdoor types, electrical motors, etc.—in addition to steam turbines, diesel locomotives and other power machinery. Illustrated particulars are given in Publication No. 95057.

Integrally Cast Pelton Runners

By F. W. KAMBER, Dipl. Ing. ETH*

AN article in the December 1957 issue of WATER POWER entitled "Welded Construction of Pelton Wheels" proposed that water-turbine runners be fabricated as welded units. Some reasons given in support of this proposal were that the manufacture of Pelton runners as integral castings gives rise to some very real difficulties brought about by:

(a) the necessity of reproducing accurately the specified bucket profile
(b) the requirement that this bucket profile should remain unchanged in service over long periods in spite of severe operating conditions such as high water velocity, the abrasive effects of suspended solids in the water, etc.
(c) the close manufacturing tolerances laid down and the severe inspection procedures employed.

It is maintained that these difficulties can be avoided by a mixed construction in which the buckets, produced individually either by casting with subsequent machining, by the lost-wax process, or alternatively by drop forging, are then welded suitably on to a ring or disc. This method permits defective buckets to be rejected and it is claimed that separate buckets are easier to finish machine and to polish. Further, the choice of the most suitable steel grade is facilitated.

* George Fischer Limited, Schaffhausen, Switzerland.

The Development of Pelton Runners

Up to the 'thirties Pelton runners in cast steel were constructed in practically all cases by bolting separately cast buckets on to a hub. During that period

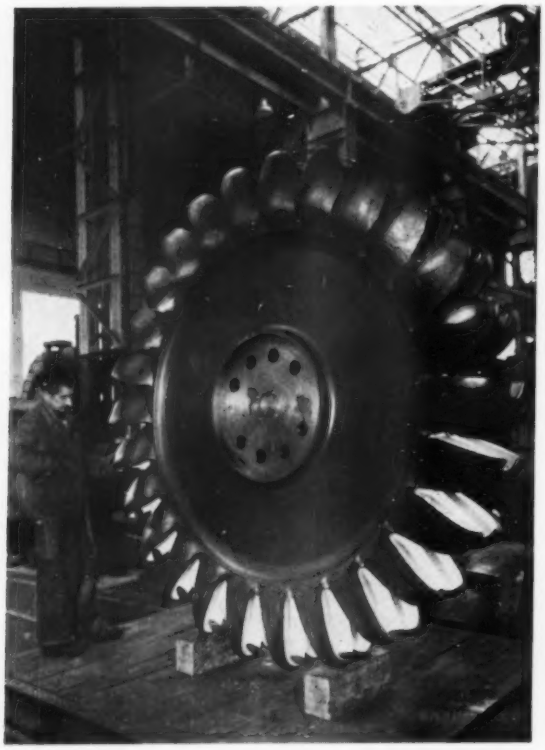


Fig. 1. Reisseck Pelton runner, 31,000 h.p., operating under the highest head in the world, 5,800 ft. 13% chromium steel; weight 4·3 tons; diameter 8 ft. 6 in.

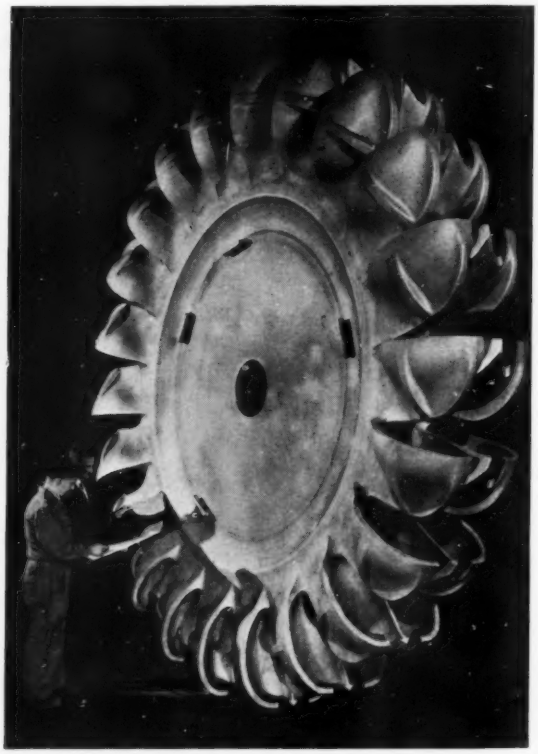


Fig. 2. Pelton runner for Kemano, developing 150,000 h.p. under a gross head of 2,585 ft. 13% chromium steel; weight 15 tons; diameter 14 ft.

Pelton runners able to withstand extremely high stresses were already being designed, as for example those on the Chandoline-Dixence power station which had at that time the highest head in the world of 5,700 ft. This Pelton runner for 21,000 h.p. had 32 separate buckets dovetailed on to the central hub without use of bolts.

In the years that followed Pelton-runner design changed more and more to the solid cast monobloc construction, i.e., to runners having buckets cast

Fig. 3. Gamma-ray inspection of Handeck II Pelton runner with 13 MeV Betatron. 2% nickel steel; weight 16 tons; diameter 11 ft. 6 in.

integrally with the hub or disc. Factors influencing this tendency included:

(a) higher allowable working stresses for the runners
(b) ease of compliance with the overall design strength
(c) more elegant and lighter design
(d) greater freedom of design
(e) use of high-tensile stainless steels which offer better resistance to cavitation.

This development on the technical design side could only take place if foundries were at hand which, by virtue of their experience and equipment, were in a position to cope with the attendant increased level of technical skill required.

Weight of Pelton Runners

Table I, giving statistics from George Fischer Limited, Schaffhausen, Switzerland, who have manufactured approximately 1,000 integrally cast Pelton runners between 1940 and 1957, shows clearly how the average weights of integrally cast runners have developed during the course of these 17 years. The weight of the heaviest runner cast to date stands at 32 tons. Runners with weights ranging from 12-24 tons are today no longer an exception, as they represent one-quarter of the runners supplied during recent years.

TABLE I.—DEVELOPMENT OF THE AVERAGE WEIGHTS OF PELTON RUNNERS BETWEEN 1940 AND 1957

Period	Average weight
1940–46	2 tons
1947–49	4 tons
1950–55	5 tons
1956	8 tons
1957	9 tons

Steel Grades

In the course of the years a new and interesting development took place in the steel grades used for Pelton runners. There was a growing tendency to replace unalloyed cast steel by low-alloy easily weldable steel and high-alloy high-tensile steel possessing good resistance to cavitation. During the Second World War runners were cast mainly in unalloyed steels because of the scarcity of alloying material at that period. After the war the number of stainless

TABLE II. — PERCENTAGE OF INTEGRALLY CAST PELTON RUNNERS PRODUCED BY +GF+ IN VARIOUS STEEL GRADES

Period	Unalloyed	Low-alloy	High-alloy	Total
	%	%	%	%
1940–1945	62	34	4	100
1946–1950	46	17	37	100
1951–1955	16	30	54	100
1956–1957	12	34	54	100
1958	6	25	69	100

Fig. 4. Magnaflux inspection of Kemano Pelton crown

Pelton runners cast in 13% chromium steel increased rapidly, and today actually more than half of the runners produced by George Fischer Limited are cast in this alloy. With regard to the low-alloy steel grades a change from the 1·5% manganese steel, predominant during the last war, to the easily weldable 2% nickel steel took place. Over the last few years roughly one-third of the Pelton runners produced in Schaffhausen have been cast in 2% nickel steel. The trend in steel grades is shown in Table II.

Output and Head

The rise in operational stresses of Pelton runners can be understood when it is realised that outputs of up to 150,000 h.p. per turbine are achieved for vertical four-jet design units as installed at the Kemano power station in Canada. On the other hand the twin turbines of the Cimego power station in Italy have a cumulative total output of 150,000 h.p. with their horizontal single-jet runners. Transport difficulties necessitated the runners for these latter turbines being designed and manufactured with a three-section Pelton crown. The Pelton runners believed to have the highest head in the world, 5.800 ft., are the Reisseck turbines in Austria.

Integrally Cast Pelton Runners Versus Fabricated Pelton Wheels

The casting process gives the designer the greatest amount of freedom when "working up" in respect to shape, dimensions etc. A Pelton runner is a complicated casting since its wall thickness varies greatly from extremely thick sections on the disc and bucket roots to the buckets themselves, which are relatively thin-walled. These wide variations in section, however, present no obstacle to advanced foundry techniques, and this ability to cast runners integrally permits a wide range in the choice of steel grade to meet the requirements for tensile strength, resistance to cavitation, weldability etc. Moreover the entire runner can be subjected to the full heat-treatment cycle in the course of the manufacturing operations. Any welding performed on this type of runner is generally to repair non-detrimental surface defects, which, after subsequent heat treatment, have no influence whatsoever on its behaviour in service.

A welded construction for a Pelton wheel is felt to offer various disadvantages and difficulties compared with an integrally cast runner. Some restrictions will have to be placed on the steel grades employed because of the differing weldability of different alloys. Welding of the buckets to the disc or rim and the inevitable stress-relieving heat treatment may give rise to difficulties such as cracks and deformation, especially when finish-machined buckets are used. One special problem is to obtain an absolutely sound weld at the bucket root especially in the case of heavy, highly stressed runners. Furthermore the cost of a Pelton runner of welded construction, finish-machined to the same accuracy as a comparable integrally cast unit will rarely be lower than the cost of the latter alternative.

Requirements for First-Class Integrally Cast Pelton Runners

As already suggested the manufacture of a solid cast Pelton runner is no easy job, but the aforementioned factors such as accurate bucket profile, resistance to wear, close dimensional tolerances and rigid inspection are by no means reasons justifying substitution of an integrally cast design for one of welded construction; they merely represent a normal technical development with which steel foundries have had to keep pace since the target is within their reach.

Fig. 5. Ultrasonic testing of Wadagawa Pelton runner. 88,000 h.p.; 13% chromium steel; weight 18 tons; diameter 11 ft. 6 in.

It can thus be said that the need to manufacture first-class integrally cast Pelton runners is the result of practical experience in this field over many years coupled with a close and regular contact with the water-turbine manufacturer and designer, as well as with the maintenance personnel in the power stations who handle the turbines and who are fully conversant with their behaviour in operation and must carry out any necessary repairs. All these aspects must be considered thoroughly by the foundry. Apart from qualified foundry personnel, accurate patterns, modern foundry equipment, especially melting and heat-treating furnaces, as well as the rough machining of the castings, all play an important role beside general experience in the manufacture of castings.

The thorough inspection of the casting by non-destructive testing methods is likewise of prime consideration. The present-day requirements which highly stressed Pelton runners have to meet with regard to the quality of material and dimensional accuracy are very exacting. These castings must not show any major defects and must be free from cracks and porosity. These specifications can only be met by thorough examination and the continuous development and application within the foundry of appropriate non-destructive testing methods such as magnetic flaw detection, ultrasonic testing and X-ray and

Gamma-ray examination. One or more of these testing methods are used for these castings. Various photographs of such examinations are shown in (Figs. 3–5). Repairs to defects found during these examinations are carried out with the utmost care. After complete removal of the defect and repeated examination it is repaired by welding, considering both the position and extent of the defect as well as the weldability of the steel grade used. If necessary the casting is preheated in a furnace, by gas torches, or by induction heating prior to being welded. After a welding repair of this type the casting is examined once more by non-destructive testing and subjected to the appropriate heat treatment.

The close tolerances of a runner and especially of the bucket profile, i.e. dimensional requirements, are met by rigid dimensional control by the various manufacturing operations in the foundry and by close co-operation between the inspection and moulding departments. Obviously the Pelton runner, prior to release for shipment, is inspected for dimensional accuracy according to the customer's drawings and correctly marked off.

Acknowledgments

The author wishes to express his thanks to the Directors of George Fischer Limited, Schaffhausen, Switzerland, for permission to publish this article. Acknowledgment is also made to Charmilles Engineering Works, Geneva; Escher Wyss Limited, Zurich; J. M. Voith GmbH, Heidenheim; Dominion Engineering Works Limited, Montreal; and Vancouver Iron Works Limited, Vancouver, for permission to publish photographs of their runners.

Raise Driving Platform

One of the most expensive tasks in underground developments is that of driving raises, which may be needed for spoil disposal, as the first stage in opening out a surge shaft, or to connect upper and lower headings when excavating a machine hall. Raising also often tends to be more dangerous than other forms of development work and any new technique or equipment that is likely to reduce costs and minimise hazards for driving raises must be of great interest to engineers.

The accompanying illustrations show a raise-driving elevator platform manufactured by Alimak Verken A.B., Skelleftéa, Sweden. Consisting basically of a platform that rides on a special track bolted to the hanging-wall of the excavation, the equipment may be used for driving vertical, inclined or curved raises. In a report on the equipment, the manufacturers state that "the new method permits the driving of raises of practically unlimited height more rapidly than was formerly possible, resulting in a substantial saving in labour cost. Moreover, the use of the platform elevator does away with much of the usual expenditure for

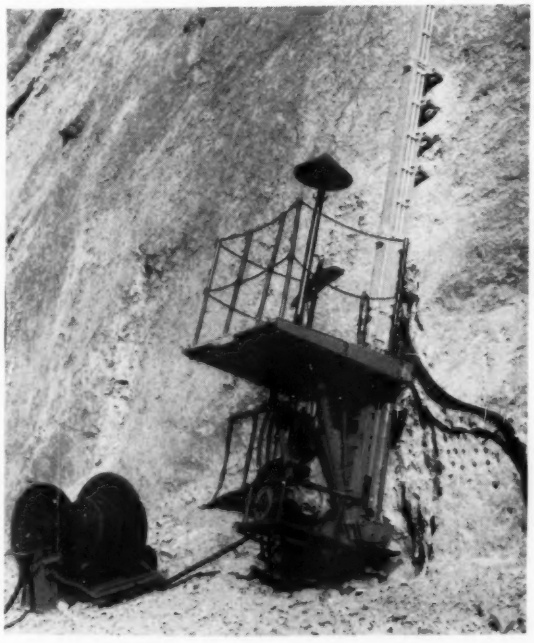


Fig. 1. The raise platform installed, for demonstration purposes, on a quarry face

Fig. 2. The platform at the top of the track ready for drilling

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The Atlas Copco Bencher comprises a rock drill mounted on a vertical pusher feed. It is ideal for service in rough terrain where wagon drills cannot conveniently be used, or for small-scale benching projects where wagon drills are uneconomical. Benching is faster and cheaper than with hand held machines. Heavier, higher capacity rock drills can be used and one man can easily operate two Benchers at the same time.

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One man can easily operate two Benchers simultaneously.

To secure the rig, bolt holes are drilled and anchor bolts and wedges placed in and driven tight. The bencher is placed on the heads of the anchor bolts and the feed is locked at the desired angle with chained wedges.
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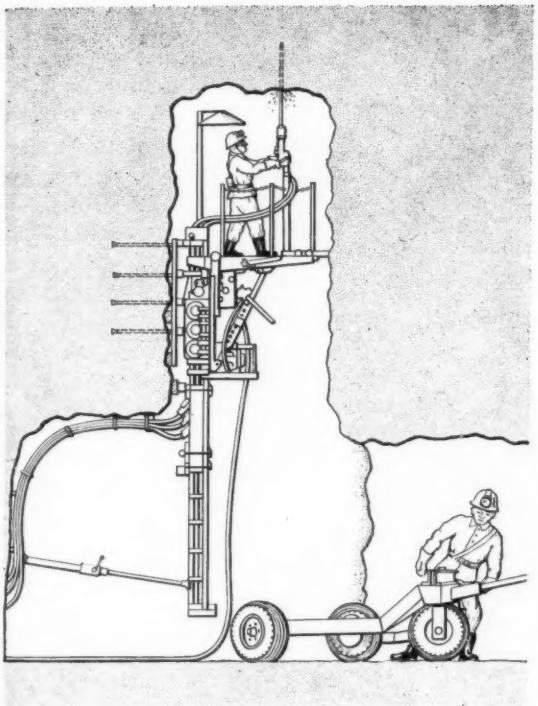

Fig. 3. Drilling in progress after the first guide rail section has been installed. Hoses from the stoper are connected to the header box installed on the top of the guide rail

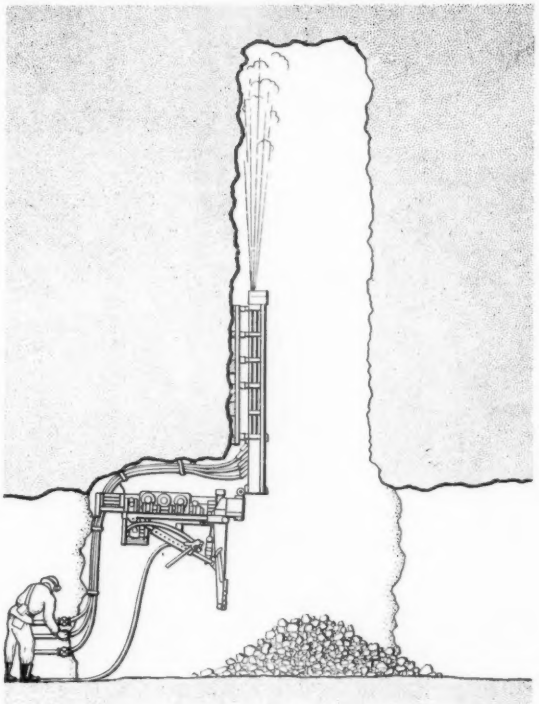

Fig. 4. Blowing out blasting fumes from the round. The platform has been brought out of the raise and a hinged section of track allows it to be protected from the effects of the blast

timbering and steel work. But the greatest gain is, nevertheless, the ability to increase the distance between working levels in the mine." In addition, the use of the system eliminates ladders and timbering thus aiding ventilation, reduces operator fatigue and travelling time in that men and equipment are transported to the working face, and does away with pipe-fitting as the compressed air and water services are contained in the track structure.

A demonstration of the Alimak drilling platform was recently arranged by A.C.E. Machinery Limited of Harlequin Avenue, Great West Road, Brentford, Middlesex, who are agents for this equipment for the United Kingdom, Australia and New Zealand. (Alimak Verken A.B. are responsible for distribution in all other overseas territories.) A quarry face was chosen so that the operation could be observed by a large number of spectators and facilities were kindly provided by The Breedon and Cloud Hill Lime Works Limited at Breedon-on-the-Hill, Leicestershire. The Consolidated Pneumatic Tool Co. Ltd. collaborated in the arrangements and provided the ancillary pneumatic tools necessary, such as rock drills and impact wrenches, as well as compressed air from a Power Vane oil-flooded rotary air compressor of 210 cu. ft. per min. (free air delivery) capacity. Two views of the Alimak platform on the limestone quarry face at the Breedon demonstration are given in the accompanying illustrations.

The elevator consists essentially of a steel platform equipped with a detachable protective bell mounted on a standard, provided to afford the driller protection when barring down after blasting. For use in a 6 ft. 8 in. square raise, the platform is 5 ft. 3 in. square, weighs 1,100 lb. and can take a maximum load of 1,100 lb. For use in an inclined raise, the platform is hinged and may be set to suit the angle that the excavation is being driven. Access to the platform is provided through a door which may be opened from above or below, and during ascent and descent the raise crew are protected from falling rock by sitting beneath the platform.

The platform runs on a rack-equipped guide rail which is supplied in 1 m. and 2 m. lengths and is extended up the raise as driving progresses. Special curved rail sections are available for use, should it be necessary to change the direction of the raise. Each rail section is made of four $1\frac{1}{2}$ in. diameter pipes welded side by side. In addition to forming the main structural member, these pipes are also used for carrying compressed air and water to the top of the raise for the drilling machines, for the passage of an electric blasting cable and for ventilation purposes. The weight of the guide rail is 27 lb. per ft. and O-rings are inserted as each section is added to ensure a water or airtight joint for the services.

Each length of track is secured to the hanging-wall of the raise by $\frac{3}{4}$ in. diameter expansion type rock bolts. The standard length for these is 800 mm. but special lengths may be needed when traversing poor ground. The track sections, after fitting together, are secured to the raise wall by two rock bolts, but every 50 ft. a section employing eight bolts is installed to act as a support member. After the track has been laid,

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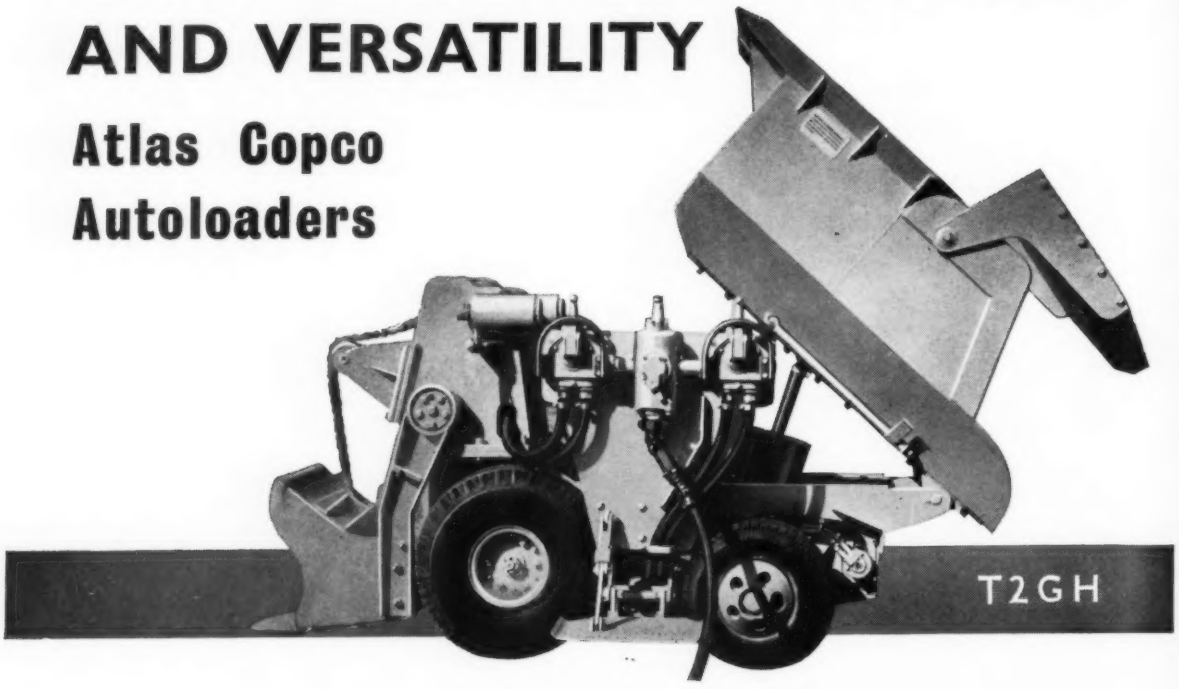
Atlas Copco Autoloaders



Operated by one man. The complete work cycle — mucking, transport and dumping can be carried out by one man. This reduces labour costs considerably.

Independent of track. Owing to the fact that the autoloader is not rail bound it has an unlimited loading width. Mucking can be carried out just as easily in narrow drifts as in large underground excavations. In addition costs for track laying are eliminated.

Low maintenance costs. Rubber tyres reduce stresses on the machine resulting in lower maintenance costs. The tyre costs per ton loaded vary with working conditions but generally these are extremely low.

Another advantage of pneumatic tyres is that the loader can run over the air hose without the least risk of hose breakages.

High capacity. The capacity is dependent on the distance between the loading and dumping sites, but for instance, with a haulage distance of 70 ft., capacities of up to 55 cu. yds. of material per hour have been obtained.

Many ranges of application. Being independent of tracks the machine can operate over larger areas than track-bound loaders. It can be dismantled quickly and easily if shaft dimensions make transport difficult.

This machine is available in two versions, T2G and T2GH. T2GH has a higher discharge height and is designed especially for dumping on conveyor belts.

Atlas Copco autoloaders are used throughout the world in various ranges of application such as cut-and-fill-stoping in ore mines, seam drifts in coal mines and for loading operations at the surface.

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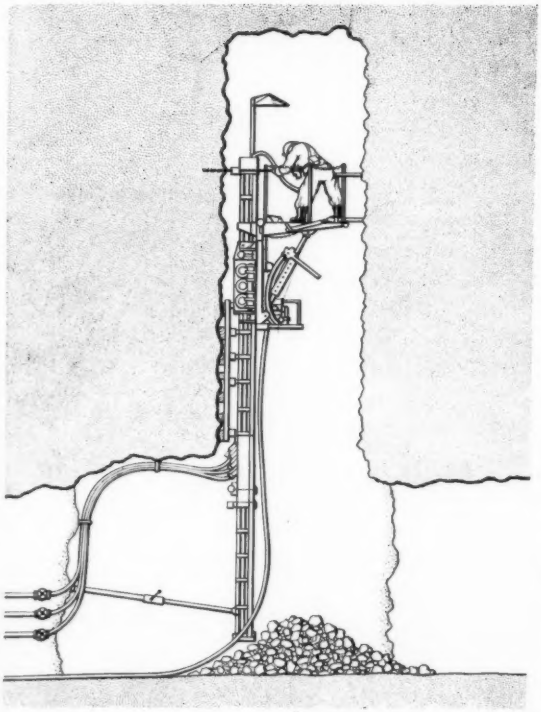


Fig. 5. After barring down, a further section of guide rail is installed and the platform run up to the top. In this drawing the two rock bolt holes are being drilled for securing the track

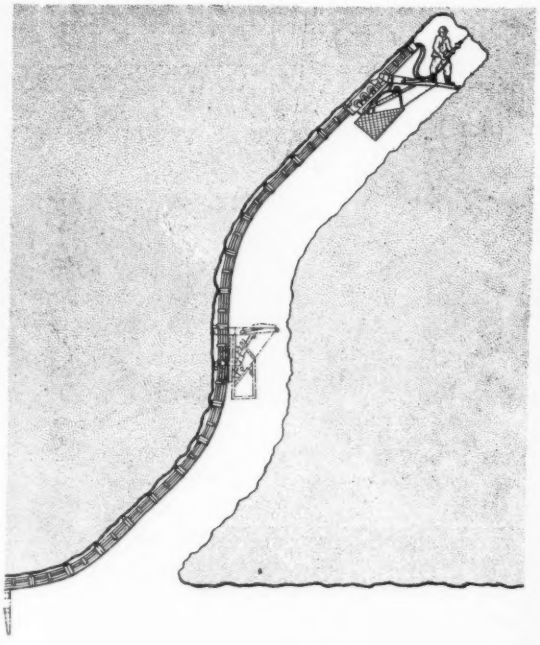


Fig. 6. Diagram illustrating the use of the Alimak platform in a compound 38–90–38 deg. raise

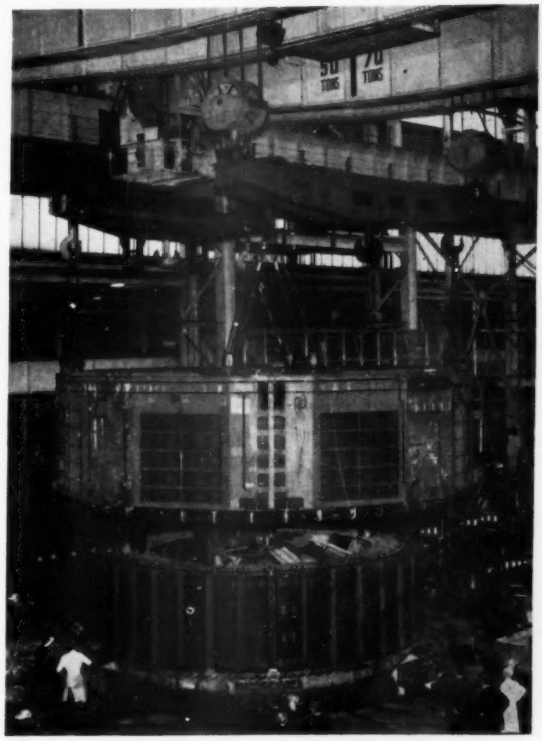
the platform is propelled up the guide rail by the engagement of three pinions in the rack that runs on one side of the four pipes, the driving motor being a 6·2 h.p. Atlas Copco air motor requiring 100 cu. ft. per min. of air at 80–100 lb. per sq. in. The speed of ascent is specified as 33 ft. per min. and when descending, 50 ft. per min. Air for the driving motor is supplied through a trailing hose that is wound on a reel mounted at the foot of the raise. Incorporated in the wall of this air hose is a telephone cable providing communication between the crew at the face and the bottom of the raise.

Should the air supply fail when the platform is at the top of the raise, it is automatically locked in position but the platform can be lowered in an emergency by operating a hand crank; in addition, the tool box on the platform contains special climbing irons, a grappling hook and life-line which the driller can use to climb down the track. The irons are fitted to his boots and engage on the rack of the guide rails.

The platform is brought to the raise site on a special transit trolley, the overall height being 8 ft. Where access headroom is limited the platform may be transported on its side and the complete equipment can be easily dismantled for handling in shaft cages.

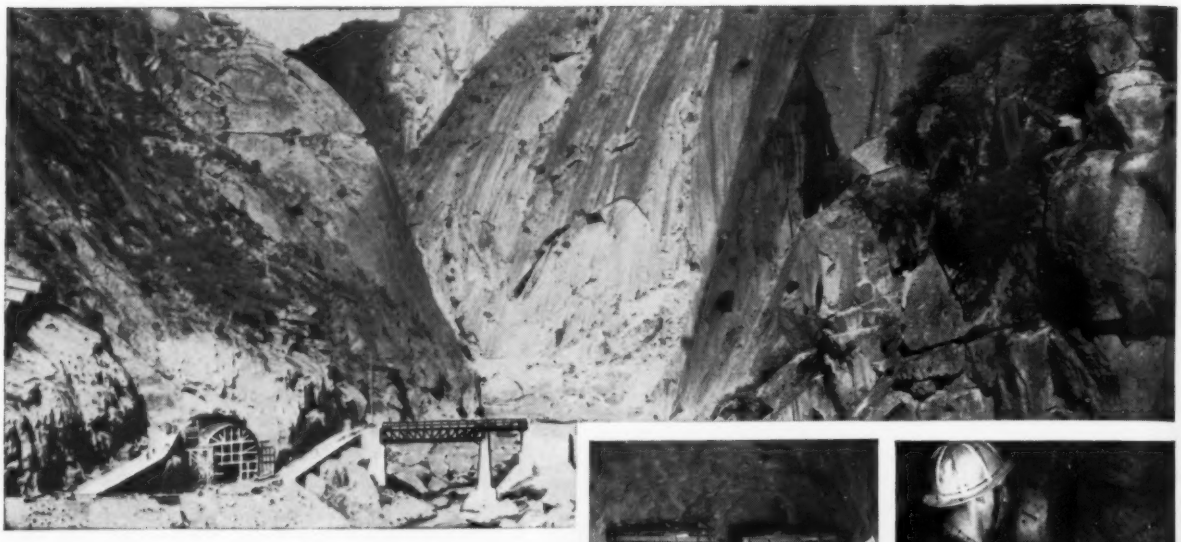
Kariba Generator Tested

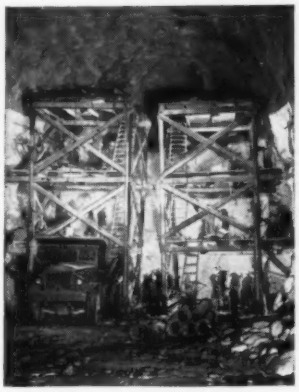
The first of the six 111,111 kVA 167 r.p.m. generators for the Kariba hydro-electric power station in Rhodesia has recently completed full-scale tests at the

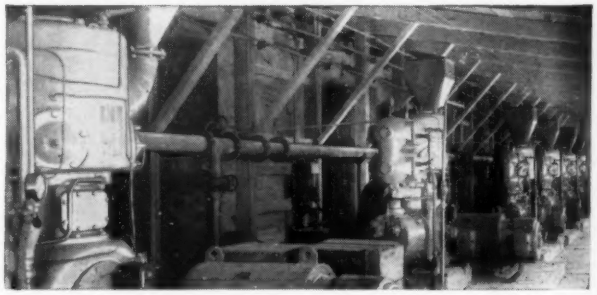


The first of the Kariba generators on test in the Metropolitan-Vickers works

WESTERN EUROPE'S LARGEST HYDRO-ELECTRIC POWER STATION







Atlas Copco pneumatic equipment and Sandvik Coromant drill steels for Spanish project

What is to be the largest hydro-electric power station in Western Europe is now being built by Iberduero S.A. at Salto de Aldeadávila. The great dam will finally tame the River Duero and enable Spain to increase her hydro-electric capacity by 25%.

ANNUAL OUTPUT — 1,700 MILLION kWh

The dam will form a reservoir for 150 million cu. yds. of water. The underground power station containing six units will have an installed power capacity of 762,000 kVA. Annual output of the project is estimated at 1,700 million kWh. This power station alone will give Spain a larger increase in installed capacity than the total national increase in hydro-electric energy during the period 1950-1954.

925,000 CU. YDS. OF ROCK TO BE EXCAVATED

All the rock drilling on the site is being done by 165 Atlas Copco rock drills using Sandvik Coromant drill steels. Tunnelling accounts for more than half of their excavation task which, in all, amounts to almost a million cu. yds. They are powered by a battery of 14 stationary compressors—types currently the leading choice for tunnelling projects throughout the world—the Atlas Copco AR3 and AR4.

MORE THAN 1,300 MILLION FEET DRILLED EVERY YEAR

Atlas Copco rock drills and Sandvik Coromant steels were developed to work together as a lightweight drilling unit. Responsible for drilling more than 1,300 million feet annually, this drilling combination is now the most widely used in the world.

A COMPLETE RANGE OF COMPRESSED AIR EQUIPMENT

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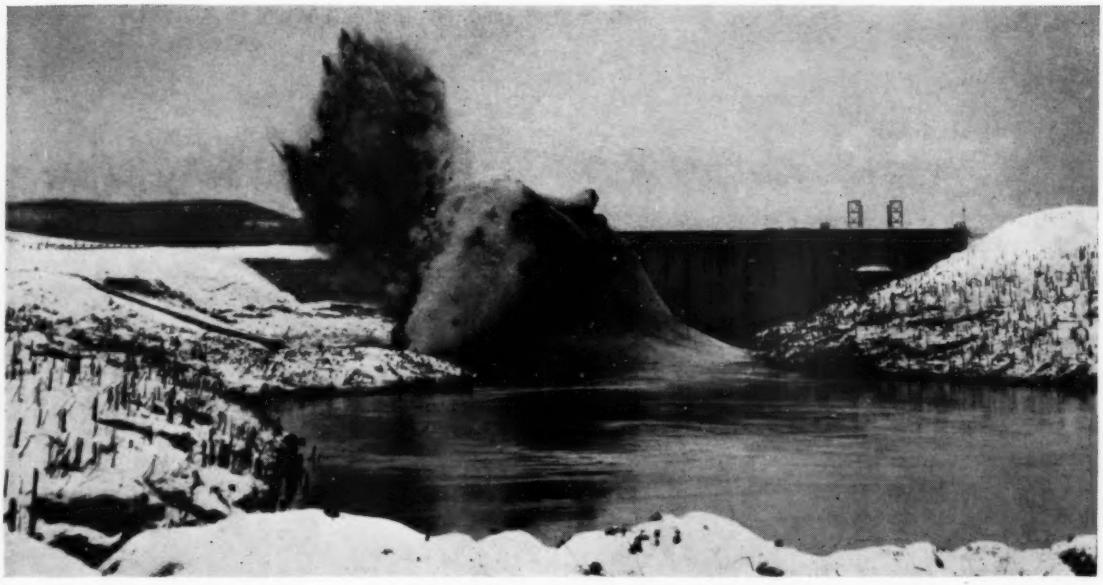
works of Metropolitan-Vickers Electrical Co. Ltd., Manchester, a member company of Associated Electrical Industries Limited. These tests were carried out for the electrical and mechanical consultants, Messrs. Merz & McLellan. The photograph shows the generator in the final stages of assembly for testing.

Chute-des-Passes Rock Plug Blown



In the article on the Aluminum Company of Canada's Chute-des-Passes development which we published in our May issue we described the proposal to place the supply tunnel under water by blowing out an underwater rock plug in the bed of the Peribonka River. This plug was successfully blown on April 19. It involved a rock mass of 30,000 tons, which was disintegrated by a charge of 60,000 lb. of explosive, leaving an aperture 100 ft. by 50 ft. The spoil fell into a sump 55 ft. in diameter and 120 ft. deep. A temporary concrete barrier behind the intake gates isolated the supply tunnel from the effects of the blast, and will be removed well in advance of August 1, 1959, when the first of the five 200,000 h.p. turbines is due to come into operation. The blast is shown in the accompanying illustration, in which the existing Passe Dangereuse dam can be seen in the background. The blast had to be controlled to avoid damage to this dam.

Snowy Mountains 330 kV Oil-Filled Cables Installed

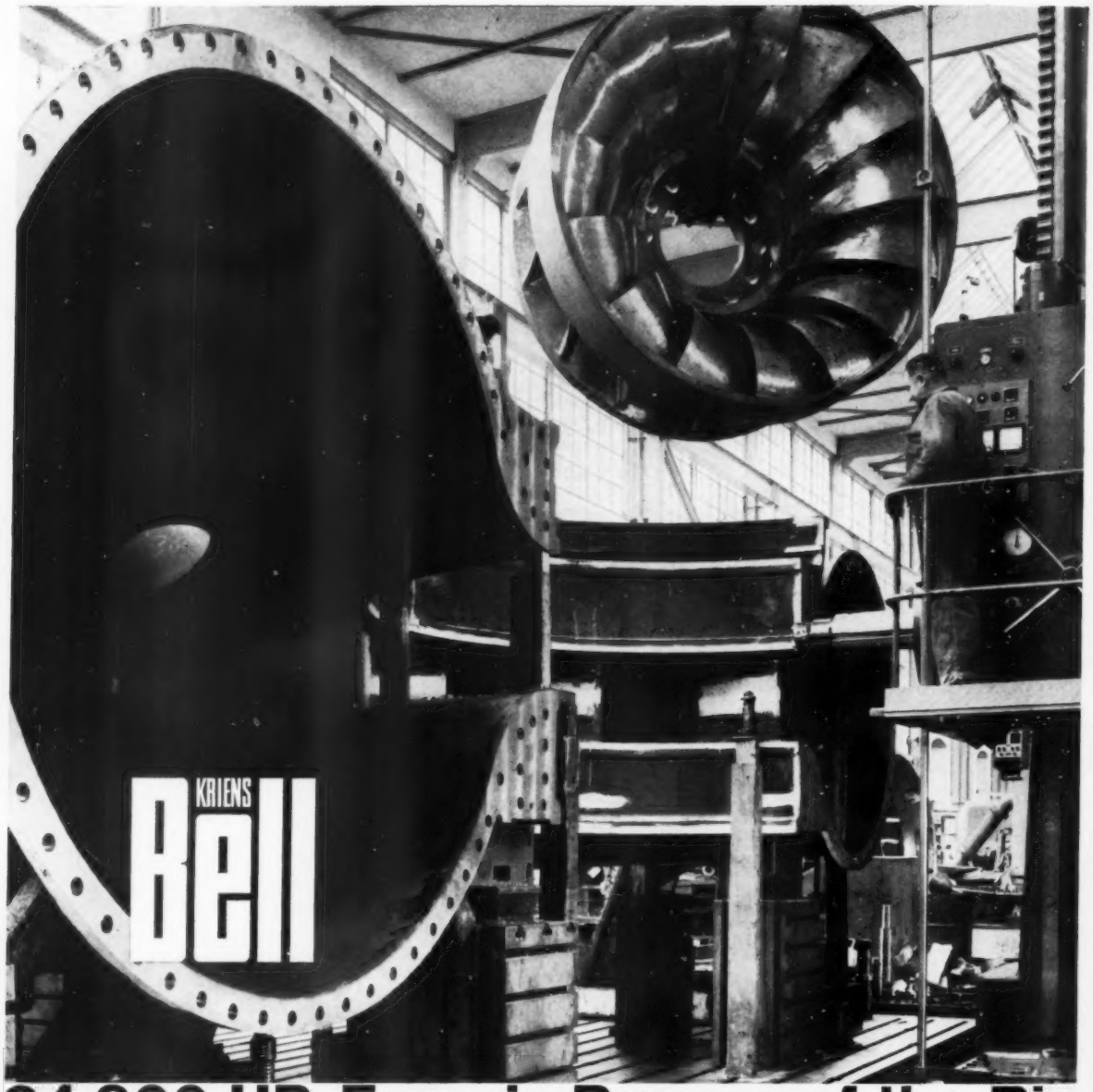
Pirelli-General Cable Works Ltd., have now completed the installation of 330 kV oil-filled cable at the T1. power station in the Tumut River valley for the Australian Snowy Mountains Hydro-Electric Authority. This is the first 330 kV oil-filled cable installation to be supplied by a British cable manufacturer and consists of seven single-core oil-filled cables with a capacity of 340 amperes per phase, grouped in two three-phase circuits with one spare cable, complete with terminations and all ancillary equipment.

The cables, which ranged in length between 507 and 543 yards, were pulled from the switchyard end and laid at 1 ft. centres in sand-filled troughs in the floor of the tunnel. As the switchyard is on the opposite side of the Tumut River to the power station, a bridge has been erected on which the cables are laid, and arrangements have been made to control the expansion movements of the cable on the bridge, due to seasonal variations of ambient temperature.

The assembly of the outdoor terminals in the switchyard and the connections to the oil-feeding pressure tanks presented no special difficulty, but the insertion of the oil-immersed terminals in the transformer connecting chamber involved considerable problems in manipulation. The connecting chambers were filled with oil degasified on site to a condition similar to the oil contained in the cable.

After installation, each cable was successfully tested at 760 kV. d.c. for 15 minutes using a 1,000 kV transportable testing equipment designed and manufactured for Pirelli-General by Ferranti Ltd.

Geared Motors, Clutches, etc. Crofts (Engineers) Limited, Bradford, Yorkshire, have forwarded a number of pamphlets describing various types of geared motors, shaft couplings, magnetic clutches, and conveyor pulleys.



24 800 HP Francis Runner of the Rio Lempa Power Station in El Salvador shown in our Turbine Erection Hall Bell builds Water Turbines of all types and sizes, Penstocks, Towers for Trans mission Lines. Power House Cranes

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Abstracts from the World Technical Press

Power Tunnels in Rock

The design criteria of power tunnels driven in rock are discussed. Determining the tunnel diameter and grade is first dealt with, and the rock loads likely to occur through roof yield are assessed. Separate paragraphs are devoted to elastic stresses in rock and to the rock stresses caused by internal pressure. In the sections that follow the author discusses the design of tunnel lining to cope adequately with internal pressure head, buckling resulting from external pressure, and provisions for drainage. Expenditure can be substantially reduced by a layout consisting, where conditions permit, of a long stretch of unlined tunnel with a slight gradient in the upper reaches, followed by a steep steel-lined short section connecting at its downstream end with the surge tank or the power house. Such a pattern would also reduce not only the hydrostatic pressure inside the tunnel to an appreciable extent, but also the external pressure resulting from seepage through surrounding material. (H. D. Sharma, *Indian Journal of Power and River Valley Development*, Vol. VIII, October 1958, p. 5, 8 pp., 5 ff.)

Water as a Source of Energy

This paper is a reprint of the lecture given under this title at the French Pavilion at the Brussels Exhibition in September 1958. It begins with a historical survey of water power, from the waterwheel known 1,000 years B.C. to modern hydro-electric generating units. The word "turbine" was first used by Burdin, a teacher at the St. Etienne Mining School, and a few years later, in 1833, the first machine of that name was being operated industrially by Fourneyron, a pupil of Burdin's. Thirty-nine years later, Gramme's dynamo made its appearance, thus opening the road to long-distance transmission of water power by electricity. Special stress is laid in this paper on multipurpose developments and their importance for the rehabilitation of undeveloped countries. Detailed descriptions of the Rhone installations between the Swiss frontier and the Mediterranean are included. (Pierre Delattre, *La Technique de l'Eau*, Vol. 12, No. 142, October 15, 1958, p. 13, 4 pp., 3 ff.)

Concreting at Large Construction Sites

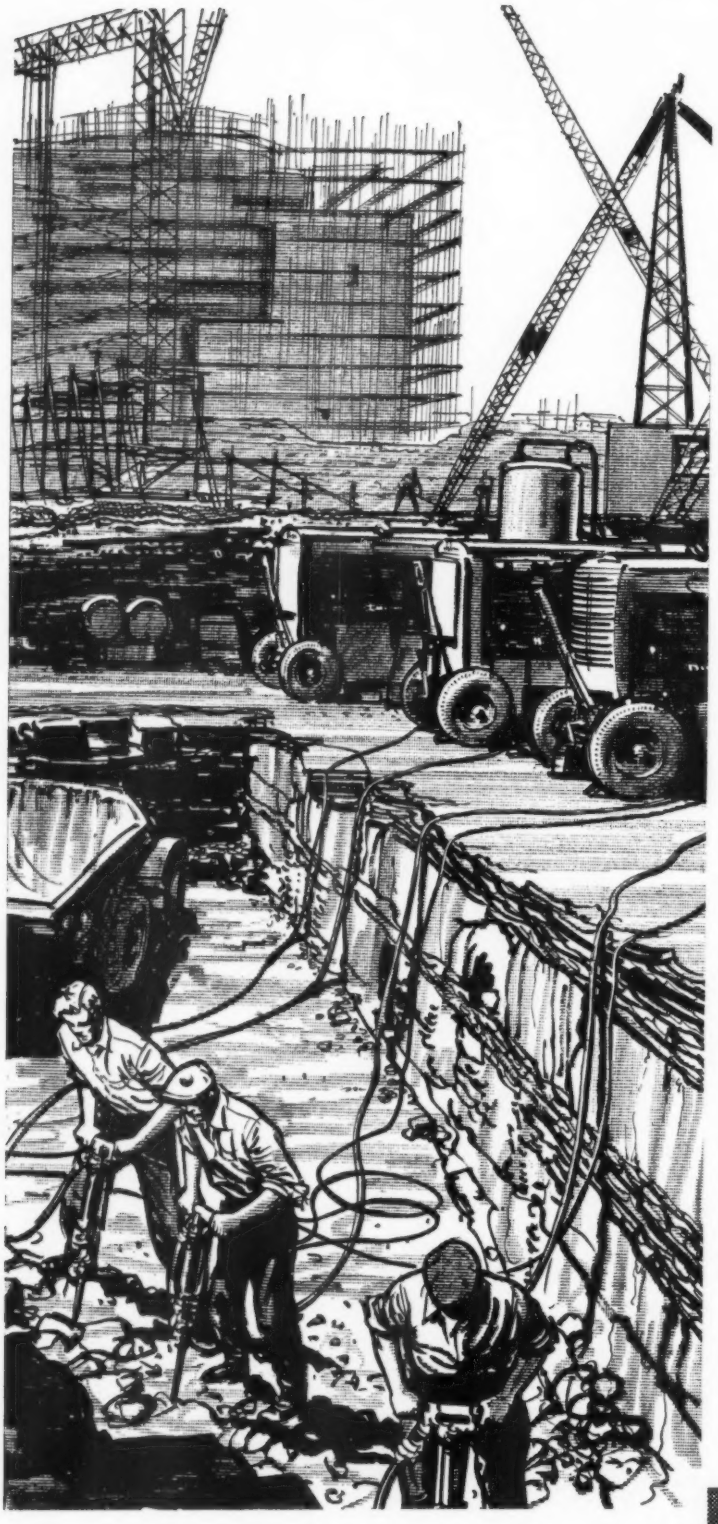
This article reproduces the paper read at the study sessions held in Locarno on March 20 to 22, 1958, on problems arising out of the use of concrete, and deals especially with the preparation of concrete intended for large-scale works, its transport to site, and its placing. The author lists at the outset the properties required in concrete, especially in connection with dam building, and then describes in broad outlines the process of preparation as well as the various methods applied to the conveying of concrete ready for use from the concrete tower to the construction site. Placing, curing and compacting are then discussed at length. In his conclusion, he emphasises the importance of having a faultless organisation for the various operations, and the employment of the most efficient machinery obtainable. The figures given for Grande Dixence and Mauvoisin for 1957 are really impressive: 1,015,000 and 788,000 cu. m. respectively, corresponding to daily average outputs of 6,800 and 4,700 cu. m., and 9,150 and 8,037 cu. m. maximum. (Prof. G. Schnitter, *Wasser- und Energiewirtschaft—Cours d'Eau et Energie*, Vol. 50, No. 10, October 1958, p. 277, 8 pp., 11 ff.)

Electrification in Turkey

This brief illustrated survey describes the two main projects now in course of construction in Turkey—the 1,000 MW Keban scheme, downstream of the confluence of the Euphrates with its tributary, the Murat River, and the 600 MW Rezuk plant on the Tigris, upstream of the Syrian border. In both instances concrete gravity dams are provided, the power houses being backed by the toe of the dam. Reservoir capacity will be 10 million and 9,000 million cu. m. respectively. The plants are scheduled to be in operation at the end of 1958. Particulars are also given of the first stage of the Sakaria River development, Hirfanli on the Kizilimak River, Demirköpru on the Gediz River, and Seyan on the river of the same name. With these four plants and all hydro-electric and thermal plants already in service, an agregate yearly production of 3,000 million kWh is expected. (*La Houille Blanche*, Supplément graphique, Vol. XIII, No. 6, November 1958, p. 661, 6 pp., 10 ff.)

Sedimentation in Reservoirs

The problem of sedimentation control in reservoirs is discussed at length. Its worst aspect is that it is practically impossible to remove the solid materials brought down by flowing water. Silting by bed load is restricted in volume but occurs mainly where it is least wanted and is apt to silt up flood-protection areas and diminish the useful volume of the reservoir itself. Appropriate measures taken in the supply channels may reduce it by 10 to 30%. Suspended load is a much greater hazard as to volume though it is deposited at less disturbing places, that is, in dead space and in the lower useful space of the reservoir. Precautions taken in the drainage area may prove efficient. There are also in may instances possibilities of preventing the suspended load from entering the reservoir, and thus restricting substantially the extent of sedimentation. Unfortunately not much research has been undertaken in this respect, and we badly lack practical experience. If the evil of sedimentation cannot be avoided, at least it can be lessened. Above all, emergency silt-storage spaces must be provided and kept ready to accommodate the unwelcome load before it reaches the reservoir. When silting by bed load is expected, the right places for these storage spaces are in the flood-protection areas and in the upper part of the useful space of the reservoir. This is the reason why, as a rule, valley-closing dams leave but small dead spaces in the reservoir. On the other hand, when silting by suspended load threatens, the lower dead spaces must be enlarged, as has been done in India at Hirakud and Bakhra. In the instance of the



Taylor Woodrow chose Holman

Reliability pays at Hinkley Point

The world's largest atomic power station, with a capacity of half a million kilowatts, is taking shape at Hinkley Point, Somerset. The contract, for the Central Electricity Generating Board, is being carried out by the English Electric, Babcock & Wilcox and Taylor Woodrow Atomic Power Construction Co. Limited.

Compressed air equipment plays a very important part in its construction; Taylor Woodrow chose Holman for the job. Batteries of compressors, rock breakers and chipping hammers with the well-known Holman reliability built into the design are taking shift after shift of rigorous work without faltering, beating construction schedules and slashing operating costs.

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Egyptian high dam, no more than 30,000 million cu. m. of dead space has been provided out of a total capacity of 120,000 million cu. m. Assuming a degree of clarification of 100%, the aggregate average suspended load depositing and remaining in the reservoir is 0·6 kg. per cu. m. In the second place, expected silting can be kept in check by making provision for raising the dam crest at a later date—a provision which should also prove useful in satisfying an increasing demand for water. The author concludes with the remark that sedimentation control is a long-term procedure and that the problems which confront us today are unlikely to meet with a solution in our lifetime. (Prof. Dr. Ing. Fritz Hartung, *Die Wasserwirtschaft*, Vol. 49, No. 1, January 1959, p. 3, 10 pp., 21 ff.)

Concrete Research

The series of investigations described and discussed in this report were carried out under the auspices of Associazione Nazionale Imprese Produttrici e Distributrici di Energia Elettrica (ANIDEL) at the laboratory for materials used in hydraulic structures attached to the Rome Faculty of Engineering, Institute of Hydraulic Structures and Plants. These investigations were devoted to experimental research on the coefficients of thermal expansion of aggregates, concretes, mortar and cement paste. The report deals in its first part with the results obtained outside Italy in the same field of research, and reviews the work of well-known specialists such as W. H. Parsons and W. H. Johnson, T. F. Willis and M. E. de Reus, Leonard J. Mitchell, and others, whose publications are mentioned in the bibliography appended. Part II is devoted to the Rome Laboratory's tests, first describing the equipment used, including apparatus for measuring the variations of the samples in length, the sample thermometer divided in fifths of a degree, a thermo-conditioning cabinet (with psycrometer), a mercury hygrograph, etc. The method applied to the tests is then explained, and further paragraphs follow on the measurement of the electrodynamic moduli, the characteristics of the materials tested, and the results achieved with the various materials used. Conclusions are drawn for each group of materials separately. (Dr. Ing. Alessandro Palmieri, *L'Energia Elettrica*, Vol. XXXV, No. 12, December 1958, p. 1195, 21 pp., 4 ff., 23 graphs, 4 tables.)

Evolution of Turbines

This article is not intended as a report on all the progress that has ever been made in the design of hydraulic turbines, but it shows what the trends have been, and emphasises certain methods and designs that have been used by some of the more important turbine manufacturers. Only the three principal types of machine are considered, namely Pelton, Francis and Kaplan, because one of these can nearly always be designed to satisfy the operating conditions, whatever the head and discharge may be.

It is particularly interesting to note some of the reasons for the increased popularity of the Francis, as compared to the Pelton, during the past decade. Although the main reason is one of economy, there are other important advantages, such as less cavitation because the velocity of water is lower; less loss of efficiency caused by wear; higher operating speed and consequently a lighter, more compact unit; higher output capacity per machine; better efficiency between two-thirds and maximum load; full use of the total head available and more stable operation under variable heads. The Pelton also has some advantages over the Francis; the latter type is particularly subject to wear if the water contains a high percentage of sand in suspension and it should only be used under high heads if the water is clean; if cavitation is to be controlled, the Francis turbine must sometimes be installed at a very low elevation, resulting in heavier expenditure and larger buildings and equipment; finally, the Francis is less efficient at low loads than the Pelton.

Although the development of stainless-steel runners has greatly increased the range of heads for which the Francis turbine can be used, much of the progress in design is due to extensive tests on scale models. The use of special steels reduces to some extent the effects of erosion by sand and, providing the conditions allow, the advantages of the Francis far outweigh the disadvantages in the majority of cases.

During the past few years, there has been a tendency to use the Kaplan in preference to the Francis for heads between 30 and 70 m., mainly because, as already mentioned, the latter is more efficient under medium and high variable heads.

It is not yet possible to state categorically that one type of turbine should be adopted in preference to another under given operating conditions, but experience has shown what the future trends of design are likely to be and has also demonstrated that engineers responsible for the various aspects of a development must collaborate closely if the optimum efficiency is to be achieved. (Th. Bovet, *Bulletin Technique de la Suisse Romande*, No. 4, February 14, 1959, p. 37, 14 pp., 14 ff.)

Dam Building in Eastern Germany

A short survey is given of the multipurpose projects now being carried into effect in the area comprised between the Harz mountains, and the Elbe and Saale rivers, a region which, before the war, had been much neglected in respect of hydro-electric development. Following the improvement of water supply in the region of the Ore mountains, the first dam in the eastern Harz was erected across the Wipper river in 1951–1952, and has since proved an efficient bulwark against floods while ensuring, at the same time, a supply of water to the industries of the Hettstedt area. In 1952 construction work began on the development of the Bode valley. The "Bodewerk," as the scheme is called, is an all-purpose system of dams and reservoirs utilising to the full the water of the two Bode rivers which unite at the foot of the Harz mountains to form the Grosse Bode. At this spot, the two earth-fill dams in course of construction will create flood-control reservoirs with a storage capacity of up to 5,000 million cu. m. These reservoirs will take up the initial high flood waves of the twin Bode rivers, and then release the water in practically equal quantities to transfer reservoirs farther downstream. One of these reservoirs, near Rübeland, 1·2 million cu. m. in capacity, is closed by a dam 110 m. long and 18 m. high, and will return part of the water to the lower stretch of the Grosse Bode, while the major part will

be conveyed through a 1·7 km. tunnel to the Rappbode dam, the largest in Germany. This concrete structure, 420 m. long and 105 m. high, closes the Rappbode valley between two high ridges, thus creating a lake 8 km. in length with a storage capacity of 110 million cu. m. Several minor dams and reservoirs to operate in co-ordination with the Rappbode dam are being built. Tunnels convey the water to central waterworks whence a long-distance distribution system 427 km. in aggregate length will supply 60 million cu. m. of pure drinking water to the industrial centres of Magdeburg and Halle-Merseburg, not to mention a supply of industrial water. If required this increase can be doubled during 150 days of the year. The main advantage of the scheme is that it will ensure a thoroughly regular supply of water from the Bode rivers, even during the dry season. Extensive hydro-electric facilities will also be provided, among which a large power station at Thale which will be fed from a tunnel with a head of 164 m. (Gerhard A. Kegel. *Indian Journal of Power and River Valley Development*, Vol. VIII. No. 10. October 1958, pp. 28 to 30, 2 ff.)

Trinity Dam

An account is given of the progress of work at the 537 ft. high Trinity dam, which is the principal feature of the Bureau of Reclamation's Trinity River Division of the Central Valley project in northern California. This dam, which is to be one of the highest earthfill structures in the world, is being built on the Trinity river about 8 miles north of the town of Lewiston. About 29 million cu. yards of earth and rock—a record for the Bureau of Reclamation—will be placed in the embankment. Other characteristics are: 2,450 ft. crest length, 40 ft. crest width, 2,600 ft. maximum base width. The maximum capacity of Trinity reservoir is 2,500,000 acre-ft. and the active storage capacity is 2,160,000 acre-ft. Trinity dam and other structures will ultimately make possible an average yearly diversion of 865,000 acre-ft. of surplus waters from the Trinity river water-shed to the adjacent Sacramento river basin, thus augmenting the water supply of the Central Valley Basin and putting to beneficial use a huge amount of water which is now wasted. The 1,700 ft. of head created by the diversion will ensure the production of 1,000 million kWh annually in four plants aggregating 400 MW. One of the power plants will be erected at the toe of Trinity dam. The plan of development and construction is described in detail, and separate paragraphs are devoted to the spillways, penstock and outlet facilities, and auxiliary outlet works. (Carl J. Hoffmann and William E. Collins. *Indian Journal of Power and River Valley Development*, Vol. VIII, No. 7, July 1958, p. 7, 7 pp., 9 ff.)

Power Development in India

A symposium under the title of "Power Development in India" was held recently at Delhi under the auspices of the Indian Science Congress, and this special issue of the journal quoted has been devoted to the reproduction of all the papers presented. The Congress was inaugurated by H. M. Ibrahim, Union Minister for Irrigation and Power, and was presided over by Dr. M. Datta, Chief Engineer of the West Bengal Electricity Board, who gave an excellent survey entitled "Power Supply in our National Planning." Sixteen other papers were presented, all by leading authorities in the Indian power-supply organisation. Some of these papers study the Indian power scene as a whole; others review the power position in the various States; and others deal with special designs developments such as transmission towers, axial-flow turbines, and high-pressure steam stations. The papers comprising the symposium give a comprehensive and up-to-date survey of the present position in India and of future plans and prospects. (*Indian Journal of Power and River Valley Development*, Vol. 8, No. 12, 118 pp.)

Dam Building in Italy

On the occasion of the Sixth Internationl Congress on Large Dams, the undermentioned Journal of the Italian Ministry of Public Works published a detailed survey of all the Italian dams either in operation or in course of construction. The structures listed numbered 361, of which 70 are in process of construction; they include only dams over 10 m. in height or creating a storage capacity above 100,000 cu. m. From Table II on page 437, which covers all dams built since 1830, the 1921–1930 decade emerges as the record period with 107 structures; this same decade also marked the peak of the use of masonry in the construction of gravity dams. The dams are divided into four main groups—gravity dams, arched dams, earth and rockfills, and river barrages. Table III, page 444, gives the main characteristics of some of the major arched structures. This survey also includes a review of the evolution which has taken place in the construction of the various types of structures. Two appendices give a detailed list of all dams built in the various provinces of Italy up to June 30, 1958, and all structures in progress at the same date. (Editorial, *Giornale del Genio Civile*, Vol. 96, No. 7/8, July–August 1958, p. 433, 31 pp., 14 ff., 3 Tables.)

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Announcements for this column can be accepted up to the 8th of the month for the following month's issue. The charges are fourpence per word with a minimum of 10s. Box No. facilities 2s. 6d. extra. In order to avoid accountancy it would be appreciated if instructions to insert were accompanied with remittance.

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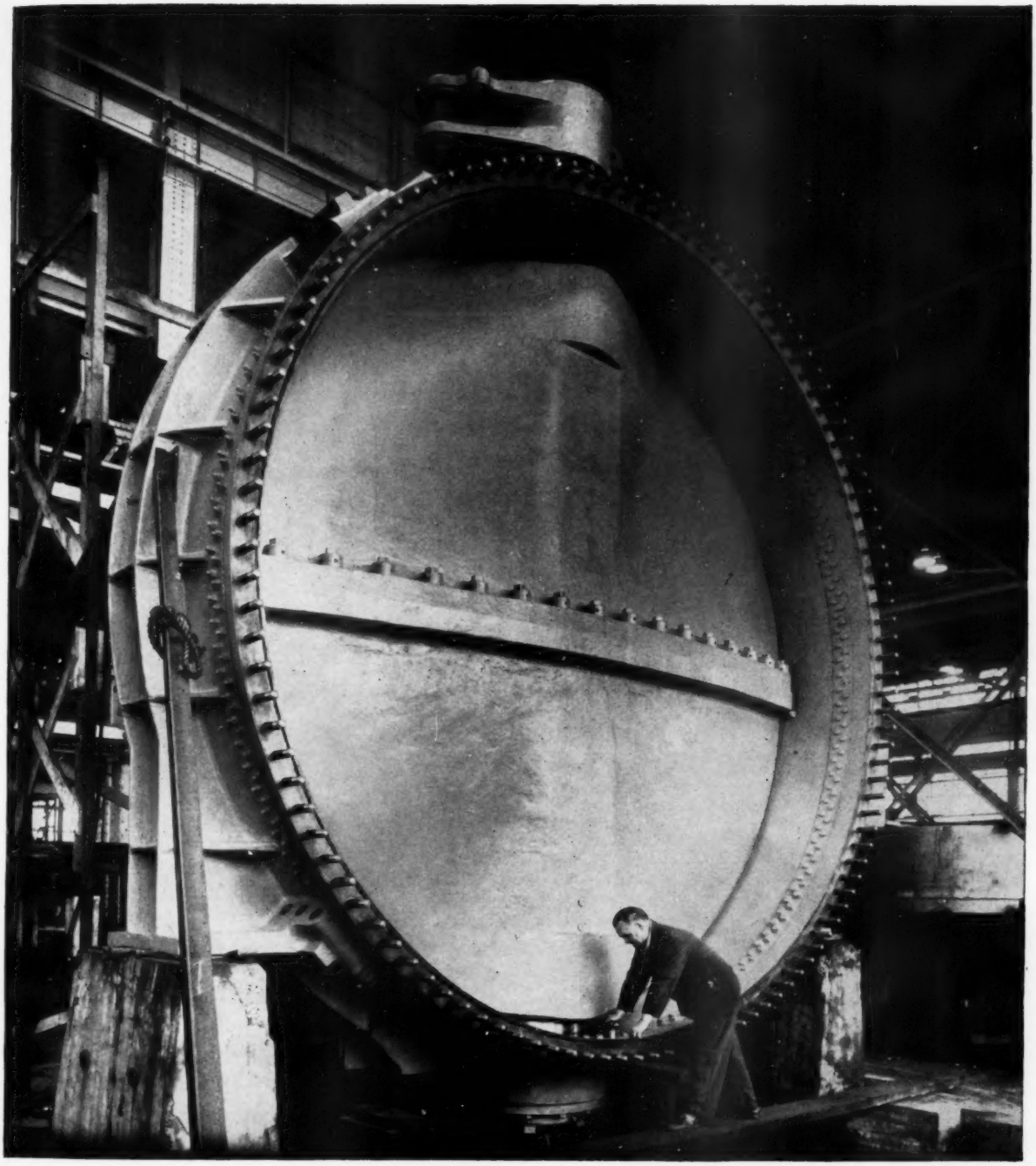

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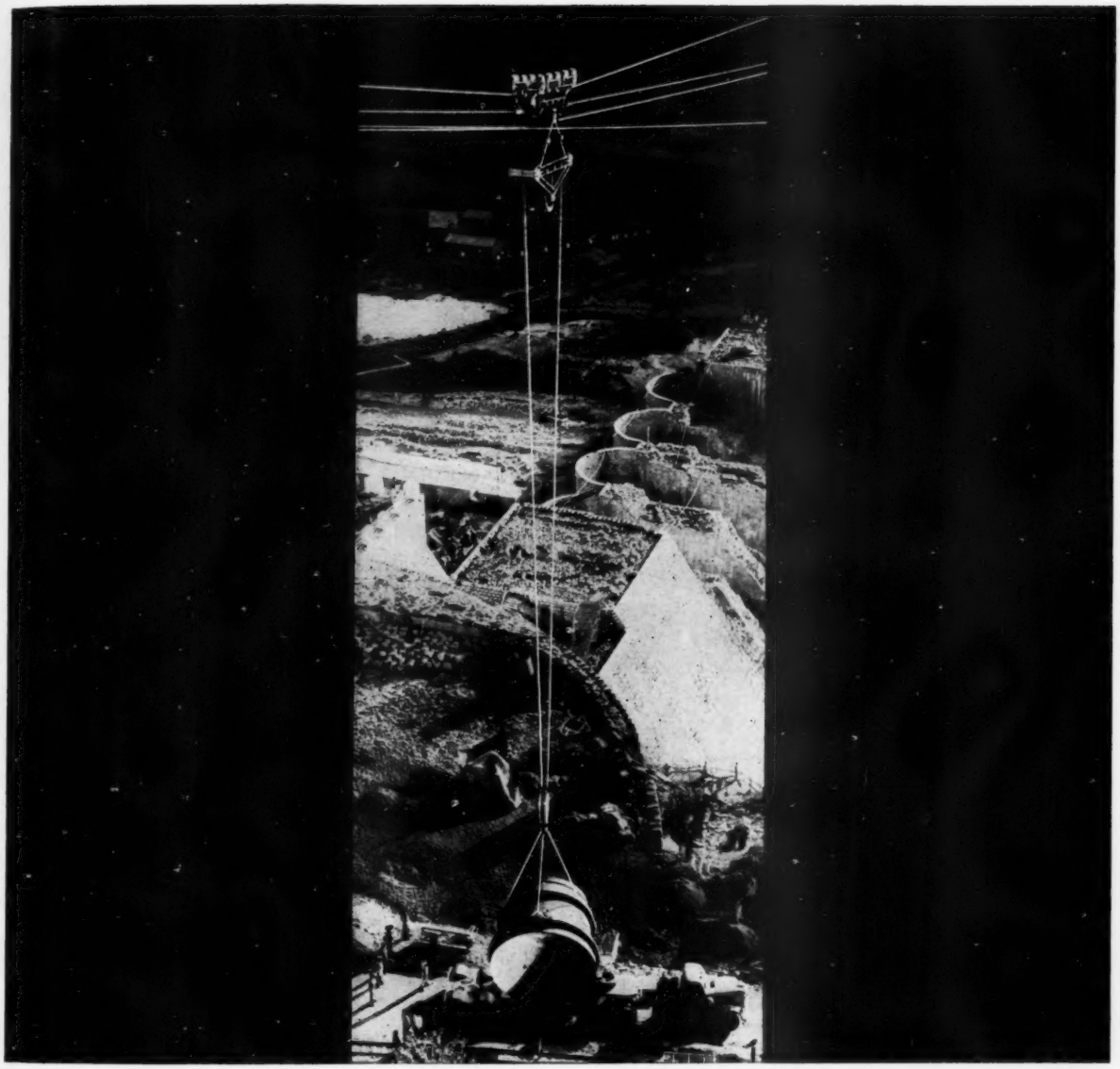

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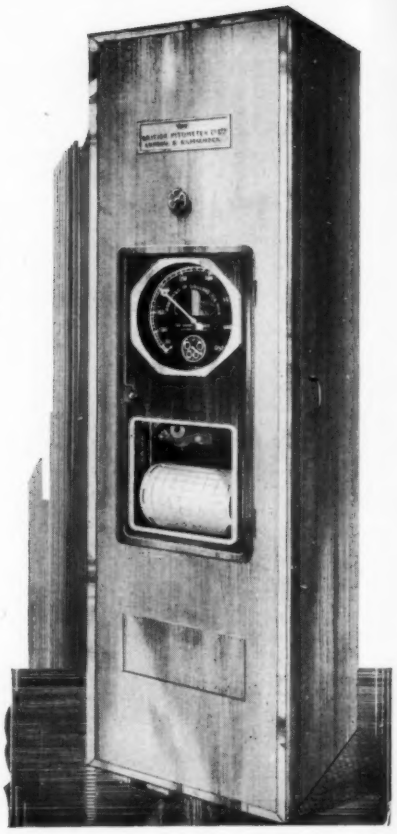

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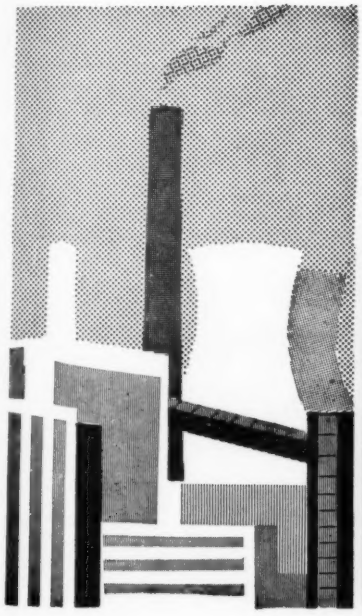

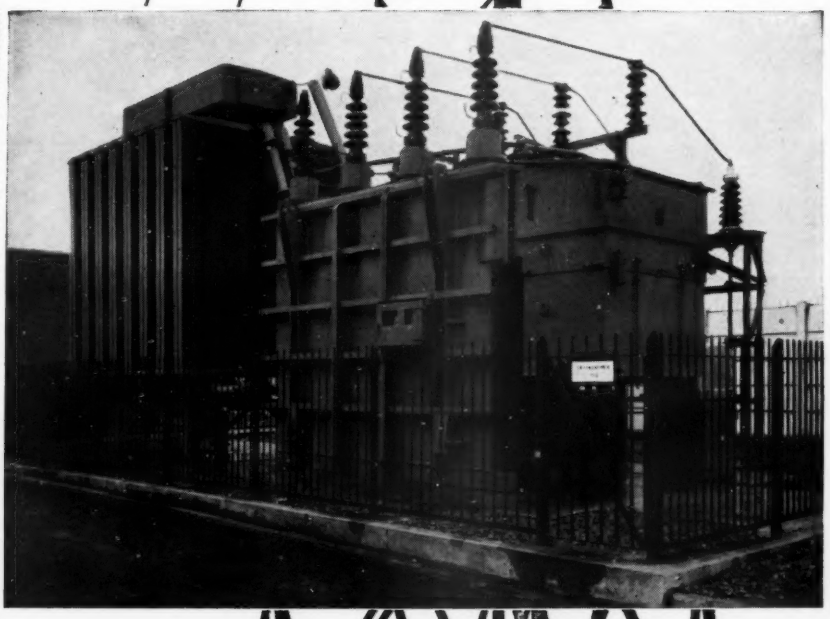

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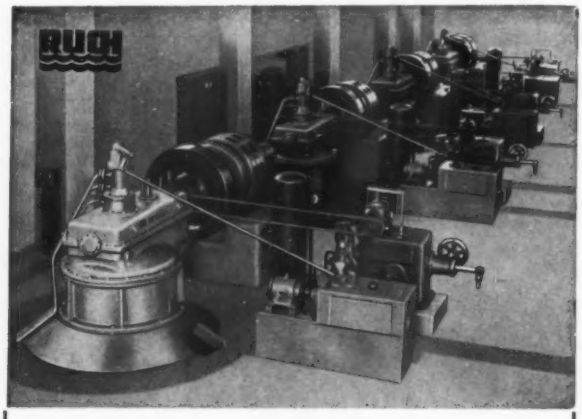

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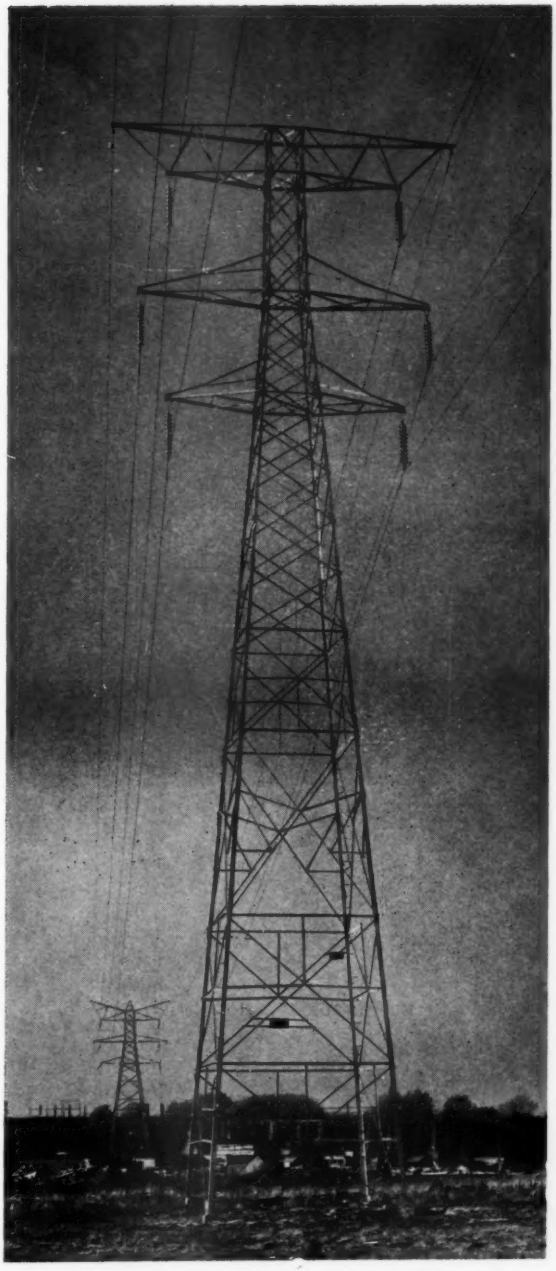

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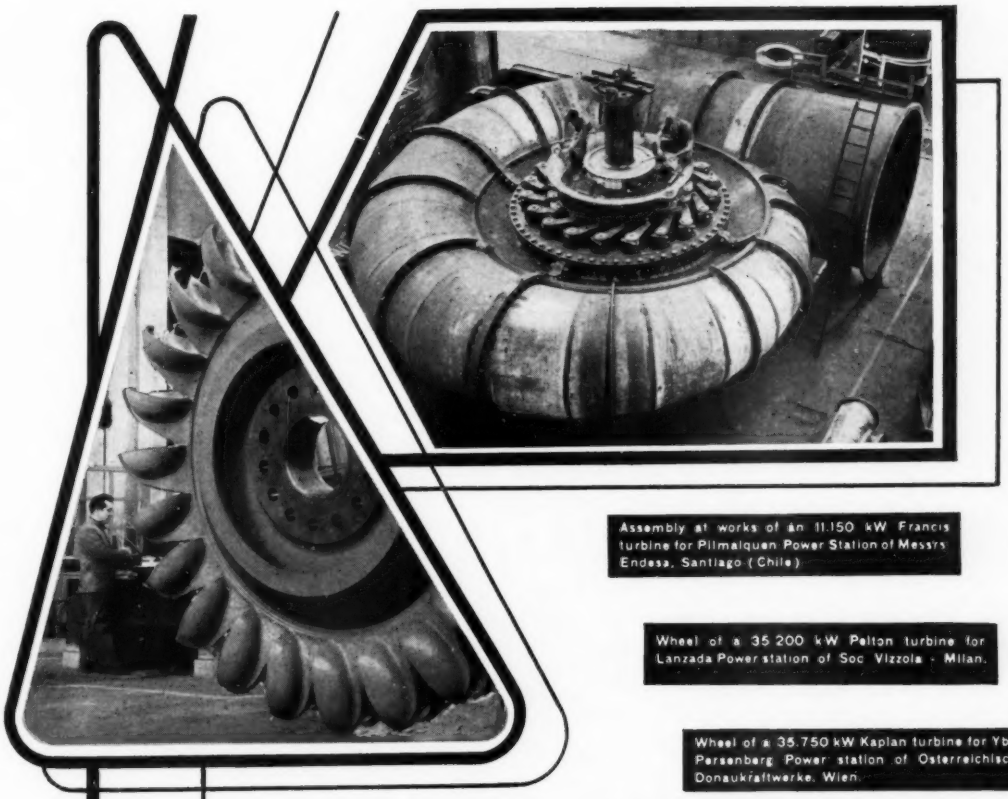

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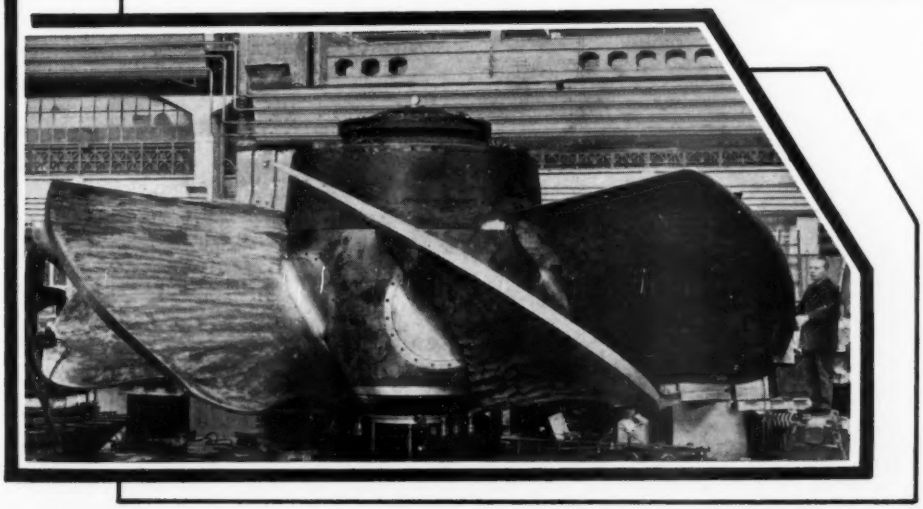
Wheel of a 35.750 kW Kaplan turbine for Ybbs Persenberg Power station of Osterreichische Donaukraftwerke, Wien.



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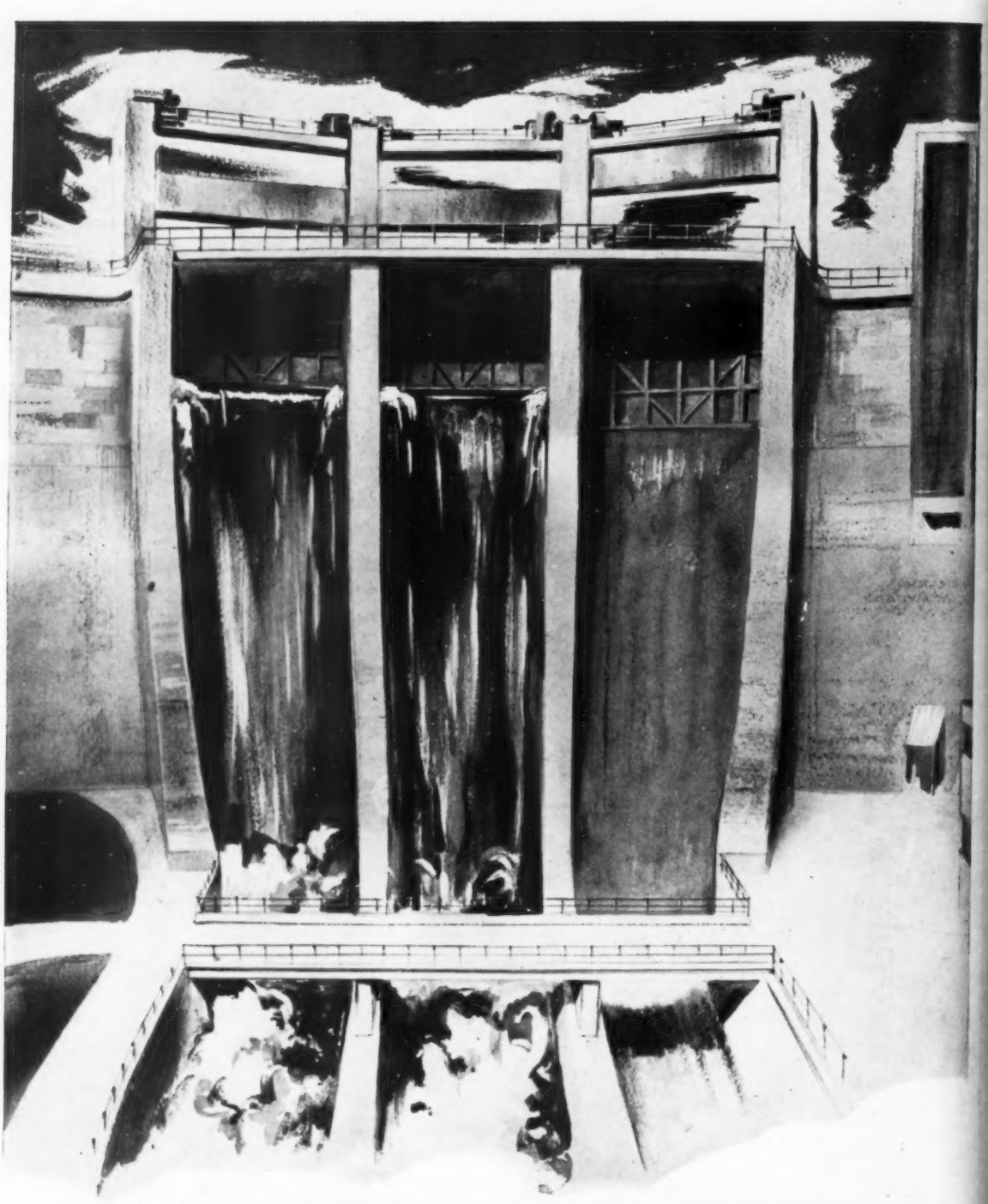

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